Paducah Site

Annual Site Environmental Report for 1999

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA ·

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Paducah Site

Annual Site Environmental Report for 1999

October 2000

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by

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Acronyms and Abbreviations

ACO	Administrative Consent Order
AIP	KDEP Agreement in Principle
AOC	area of concern
ASER	Annual Site Environmental Report
ASTM	American Society of Testing and Materials
ATSDR	Agency for Toxic Substances and Disease Registry
BBK	Bayou Creek sample location
BGS	below ground surface
BJC	Bechtel Jacobs Company LLC
BMP	Biological Monitoring Program
Bq	becquerel
BWMA	Ballard Wildlife Management Area
°C	degrees centigrade
CAA	Clean Air Act
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	Curie
COC	contaminant of concern
COE	U.S. Army Corps of Engineers
CSTP	Conceptual Site Treatment Plan
CWA	Clean Water Act
CX	categorical exclusion
CY	calendar year
D&D	decontamination and decommissioning
DCG	derived concentration guideline
DMR	Discharge Monitoring Report

DNAPL	dense nonaqueous phase liquid
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DOJ	U.S. Department of Justice
DQO	data quality objective
DSTP	Draft Site Treatment Plan
DUF_6	depleted uranium hexafluoride
DWS	drinking water standards
EA	environmental assessment
EDD	Electronic Data Deliverable
EDTA	ethylenediaminetetraacetic acid
EIC	DOE Environmental Information Center
EIMS	environmental information management system
EIS	environmental impact statement
Energy Systems	Lockheed Martin Energy Systems, Inc.
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
EPT	Ephemeroptera, Plecoptra, and Trichopetera
ESD	Environmental Sciences Division
ESS	Environmental Services Subcontractor
ETTP	East Tennessee Technology Park
°F	degrees Fahrenheit
FFA	federal facilities agreement
FFCA	federal facilities compliance agreement
FFC Act	Federal Facilities Compliance Act
FIFRA	Federal, Insecticide, Fungicide, and Rodenticide Act
FS	feasibility study
ft	foot
g	gram
gy	gray

Ha	hectare
HAP	hazardous air pollutant
hr	hour
HSWA	Hazardous and Solid Waste Amendments
IRA	interim remedial action
K-25	Oak Ridge Gaseous Diffusion Plant
KAR	Kentucky Administrative Regulation
KCHS	Kentucky Cabinet for Health and Safety
KDAQ	Kentucky Division for Air Quality
KDEP	Kentucky Department for Environmental Protection
KDFWR	Kentucky Department for Fish and Wildlife Resources
KDOW	Kentucky Division of Water
KDWM	Kentucky Division of Waste Management
kg	kilogram
km	kilometer
KOW	Kentucky Ordnance Works
KPDES	Kentucky Pollutant Discharge Elimination System
lb	pound
LC_{50}	lethal concentration 50%
LMES	Lockheed Marietta Energy Systems, Inc.
LRGA	lower portion of the RGA
LUK	Little Bayou Creek sample location
m	meter
m^2	square meter
m^3	cubic meter
MACT	Maximum Achievable Control Technology
MAK	Massac Creek sample location
Max	maximum
µCi	microCurie
µg	microgram

mgd	million gallons per day
mg/d	milligrams per day
mg/L	milligrams per liter
Min	minimum
ml	milliliter
mm	millimeter
mR	milliRoentgen
mrem	millirem
MSDS	material safety data sheet
mSv	milliSievert
mt	metric tons
MW	monitoring well
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NOV	notice of violation
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
OREIS	Oak Ridge Environmental Information System
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
pCi	picoCurie
PEMS	Project Environmental Measurement Systems
pg	picogram
pH	hydrogen-ion concentration
PGDP	Paducah Gaseous Diffusion Plant
PHA	public health assessment
POE	point of exposure
ppb	parts per billion
ppm	parts per million

PP/WM	Pollution Prevention/Waste Minimization
PSTP	Proposed Site Treatment Plan
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RD&D	Research, Development, and Demonstration
RFI	RCRA facility investigation
RGA	Regional Gravel Aquifer
RI	remedial investigation
Rn	radon
ROD	Record of Decision
SE	site evaluation
SHPO	State Historic Preservation Officer
SMO	Sample Management Office
SMP	Site Management Plan
SO_2	sulfur dioxide
SOP	Standard Operating Procedure
SOW	statement of work
SS	sediment sample location
SSAB	Site Specific Advisory Board
Sv	sievert
SVOA	semivolatile organic
SW	surface water sample location
SWMU	solid waste management unit
^{99}Tc	technetium-99
TCE	trichloroethylene (also called trichloroethene)
TCLP	Toxicity Characteristic Leaching Procedure
TLD	thermoluminescent dosimeter
TRE	toxicity reduction evaluation
TRU	transuranic element

TSCA	Toxic Substances Control Act
TUa	acute toxicity unit
TUc	chronic toxicity unit
UCRS	Upper Continental Recharge System
UE	uranium enrichment
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2	uranium dioxide
UO_3	uranium trioxide
URGA	upper portion of the RGA
USEC	United States Enrichment Corporation
UST	underground storage tank
VOC	volatile organic compound
WAG	waste area group or waste area grouping
WKWMA	West Kentucky Wildlife Management Area

Request for Comments

The U. S. Department of Energy (DOE) requires an annual site environmental report from each of the sites operating under its authority. These reports present the results from the various environmental monitoring programs and activities carried out during the year. This *Paducah Site - Annual Site Environmental Report for 1999* was prepared to fulfill DOE requirements. This report is a public document, distributed to government regulators, business persons, special interest groups, and members of the public at large.

This report is based on thousands of environmental samples collected at or near the Paducah Site. Significant efforts were made to provide the data collected and details of the site environmental management programs and still present summary information in a clear and concise manner. The editors encourage comments on this report so that the needs of our readers can be better addressed in future site environmental reports. Please send your comments to:

Paducah Site Office

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1 Site Operation and Overview

Abstract

The Paducah Gaseous Diffusion Plant (PGDP), located in McCracken County, Kentucky, has been producing enriched uranium since 1952. In July 1993, the U.S. Department of Energy (DOE) leased the production areas of the site to the United States Enrichment Corporation (USEC). DOE maintains responsibility for the environmental restoration, legacy waste management, and uranium hexafluoride (UF_6) cylinder management programs. DOE also oversees an environmental monitoring and management program to ensure protection of human health and the environment and compliance with all applicable regulatory requirements. This document summarizes calendar year 1999 environmental management activities, including effluent monitoring, environmental surveillance, and environmental compliance status. It also highlights significant site program efforts conducted by DOE and its contractors and subcontractors at the Paducah Site. ***This report does not include USEC environmental activities.***

Introduction

DOE requires that environmental monitoring be conducted and documented for all of its facilities under the purview of DOE Order DOE O 231.1 Chg 2, *Environment, Safety and Health Reporting* (DOE 1996). Several other laws, regulations, and DOE directives require minimum environmental compliance standards. The purpose of this document is to summarize calendar year 1999 environmental management activities, including effluent monitoring, environmental surveillance, and environmental compliance status, and to highlight significant site program efforts. Since April 1, 1998, Paducah Site programs have been coordinated by DOE's managing and integrating contractor, Bechtel Jacobs Company LLC. References in this report to the "Paducah Site" generally mean the property, programs, and facilities at or near the PGDP for which DOE has ultimate responsibility.

Environmental monitoring consists of two major activities: effluent monitoring and environmental surveillance. Effluent monitoring is the direct measurement, or the collection and analysis of samples, of liquid and gaseous discharges to the environment. Environmental surveillance is the direct measurement, or the collection and analysis of samples, of air, water, soil, foodstuff, biota, and other media. Environmental monitoring is performed to characterize and quantify contaminants, assess radiation exposure, demonstrate compliance with applicable standards and permit requirements, and detect and assess the effects (if any) on the local population and environment. Multiple samples are collected throughout the year and are analyzed for radioactivity, chemical content, and various physical attributes.

The overall goal for environmental management is to protect site personnel, the

environment, and the Paducah Site's neighbors, and to maintain full compliance with all current environmental regulations. The current environmental strategy is to prevent deficiencies and also to identify any deficiencies and develop a system to resolve them. The long-range goal of environmental management is to reduce exposures of the public, workers, and biota to harmful chemicals and radiation.

Background

Before World War II, the area now occupied by the PGDP was used for agricultural purposes. Numerous small farms produced various grain crops and provided pasture for livestock. Early in the war, a 6526-ha (16,126-acre) tract was assembled for construction of the Kentucky Ordnance Works (KOW), which was subsequently operated by the Atlas Powder Company until the end of the war, when it was turned over to the Federal Farm Mortgage Corporation and then to the General Services Administration.

In 1950, the U. S. Department of Defense and DOE's predecessor, the Atomic Energy Commission, began efforts to expand fissionable material production capacity. As part of this effort, the National Security Resources Board was instructed to designate power areas within a strategically safe area of the United States. Eight government-owned sites were initially selected as candidate areas, one of which was the KOW site. In October 1950, as a result of joint recommendations from the Department of Defense, Department of State, and the Atomic Energy Commission, President Truman directed the Atomic Energy Commission to further expand production of atomic weapons. One of the principal facets of this expansion program was the provision for a new gaseous diffusion plant. On October 18, 1950, the Atomic Energy Commission approved the Paducah Site for uranium enrichment operations and formally requested the Department of the Army to transfer the site from the General Services Administration to the Atomic Energy Commission.

Although construction of PGDP was not completed until 1954, production of enriched uranium began in 1952. The plant's mission, uranium enrichment, has continued unchanged and the original facilities are still in operation, albeit with substantial upgrading and refurbishment. Of the 3062 ha (7566 acres) acquired by the Atomic Energy Commission, 551 ha (1361 acres) were subsequently transferred to the Tennessee Valley Authority (Shawnee Steam Plant site) and 1125 ha (2781 acres) were conveyed to the Commonwealth of Kentucky for use in wildlife conservation and for recreational purposes [West Kentucky Wildlife Management Area (WKWMA)]. DOE's current holdings at the Paducah Site total 1439 ha (3556 acres).

At Paducah's uranium enrichment plant, recycled uranium from nuclear reactors was introduced into the PGDP enrichment "cascade" in 1953 and continued through 1964. In 1964, cascade feed material was switched solely to virgin mined uranium. Use of recycled uranium was resumed in 1969 and continued through 1976. In 1976, the practice of recycling uranium feed material from nuclear reactors was halted and was never resumed. During the recycling time periods, Paducah received approximately 100,000 tons (90,000 metric tons) of byproducts or contaminants found in the recycled uranium containing an estimated 328 grams of plutonium-239 (^{239}Pu), 18,400 grams of neptunium-237 (^{237}Np), and 661,000 grams of technetium-99 (^{99}Tc). The majority of the ^{239}Pu and ^{237}Np was separated out as waste during the initial chemical conversion to UF_6. Concentrations of transuranics (e.g., ^{239}Pu and ^{237}Np) and ^{99}Tc are believed to have been deposited on internal surfaces of process equipment, with concentrations also being deposited in waste products.

In October 1992, Congressional passage of the National Energy Policy Act established USEC. Effective July 1, 1993, DOE leased the plant production operations facilities to USEC. Under the terms of the lease, USEC assumed responsibility for environmental compliance activities directly associated with uranium enrichment operations.

Under the lease agreement with USEC, DOE retained responsibility for the site Environmental Restoration Program; the Enrichment Facilities Program; and the legacy Waste Management Program, including all waste inventories predating July 1, 1993 and wastes generated by current DOE activities. DOE is also responsible for Kentucky Pollutant Discharge Elimination System (KPDES) compliance at outfalls not leased to USEC. DOE has also retained manager and cooperator status of facilities not leased to USEC. DOE and USEC have negotiated the lease of specific plant site facilities, written memoranda of agreement to define their respective roles and responsibilities under the lease, and developed organizations and budgets to support their respective functions.

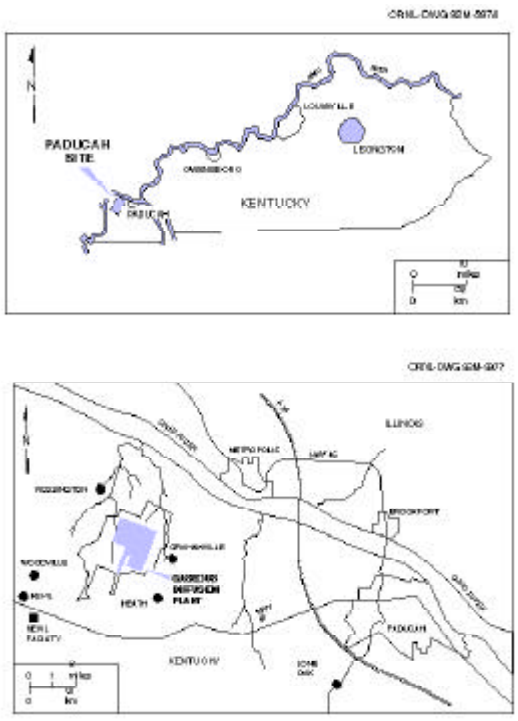

Figure 1.1 Location of the Paducah Site

Description of Site Locale

Location

The Paducah Site is located in a generally rural area of McCracken County, Kentucky. The center of PGDP is about 16 kilometers (km) (10 miles) west of Paducah, Kentucky, and 5 km (3 miles) south of the Ohio River (Figure 1.1). The industrial portion of the PGDP is situated within a fenced security area and makes up about 303 ha (748 acres). Within this area, designated as secured industrial land use, are numerous active and inactive production buildings, offices, equipment and materials storage areas, active and inactive waste management units, and other support facilities (Figure 1.2). The remaining 1083 ha (2675 acres) of DOE-owned land at the Paducah Site is comprised of approximately 279 ha (689 acres) of "buffer zone" designated as unsecured industrial, and 1131 ha (1986 acres) licensed to the Commonwealth of Kentucky as part of the 2793-ha (6900-acre) WKWMA. There are no residences on DOE property at the Paducah Site. DOE has also acquired approximately 133 acres in easements.

Three small communities are located within 5 km (3 miles) of the DOE property boundary at PGDP - Heath and Grahamville to the east, and Kevil to the southwest. The closest commercial airport is Barkley Field approximately 8 km (5 miles) to the southeast. The population within an 80-km (50-mile) radius of PGDP is about 500,000, of which about 66,000 are located within a 16-km (10-mile) radius (DOC 1994).

Climate

The Paducah Site is located in the humid continental zone where summers are warm [July averages 26°C (79°F)] and winters are moderately cold [January averages 1.7°C (35°F)]. Yearly precipitation averages about 125 centimeters (49 inches). The prevailing wind is from the south-southwest at approximately 16 km (10 miles) per hour.

Figure 1.2 The Paducah Gaseous Diffusion Plant (PGDP).

Surface Water Drainage

The Paducah Site is situated in the western part of the Ohio River basin. The confluence of the Ohio River with the Tennessee River is about 24 km (15 miles) upstream of the site, and the confluence of the Ohio River with the Mississippi River is about 56 km (35 miles) downstream. The plant is located on a local drainage divide; surface flow is east-northeast toward Little Bayou Creek and west-northwest toward Bayou Creek [commonly referred to as "Big Bayou Creek" in previous annual site environmental reports (ASERs)]. Bayou Creek is a perennial stream that flows toward the Ohio River along a 14-km (9-mile) course. Little Bayou Creek is an intermittent stream that flows north toward the Ohio River along a 11-km (7-mile) course. The two creeks converge 5 km (3 miles) north of the plant before emptying into the Ohio River.

Flooding in the area is associated with Bayou and Little Bayou creeks and the Ohio River. Maps of the 100-year flood elevations calculated show that all three have 100-year floodplains within the DOE boundary at PGDP (COE 1994).

Wetlands

More than 1100 separate wetlands, totaling over 648 ha (1600 acres), were found in a study area of about 4860 ha (12,000 acres) in and around the Paducah Site (COE 1994 and CDM 1994). These wetlands have been classified into 16 cover types. More than 60% of the total wetland area is forested.

Soils and Hydrogeology

Soils of the area are predominantly silt loams that are poorly drained, acidic, and have little organic content. Of the six primary soil types associated with the Paducah Site, five commonly have the characteristics necessary to be considered prime farmland by the Natural Resources Conservation Service, formerly the Soil Conservation Service (Humphrey 1976).

The local groundwater flow system at the Paducah Site contains four major components (from shallowest to deepest): the terrace gravels, the Upper Continental Recharge System (UCRS), the Regional Gravel Aquifer (RGA), and the McNairy flow system. The terrace gravels consist of shallow Pliocene gravel deposits in the southern portion of the plant site. These deposits usually lack sufficient thickness and saturation to constitute an aquifer but may be an important source of groundwater recharge to the RGA.

The UCRS consists mainly of clayey silt with interbedded sand and gravel in the upper continental deposits. The system is so named because of its characteristic recharge to the RGA.

The RGA consists of sand and gravel facies in the lower continental deposits, gravel and coarse sand portions of the upper McNairy that are directly adjacent to the lower continental deposits, coarse-grained sediments at the base of the upper continental deposits, and alluvium adjacent to the Ohio River. These deposits have an average thickness of 9 m (30 ft) and can be more than 21 m (70 ft) thick along an axis that trends east-west through the site. The RGA is the uppermost and primary aquifer, formerly used by private residences north of the Paducah Site.

The McNairy flow system consists of interbedded and interlensing sand, silt, and clay of the McNairy Formation. Sand facies account for 40 to 50% of the total formation thickness of approximately 69 m (225 ft).

Groundwater flow originates south of the Paducah Site within Eocene sands and the terrace gravels. Groundwater within the terrace gravels either discharges to local streams or recharges the RGA, although the flow regime of the terrace gravels is not fully understood. Groundwater flow through the UCRS is ultimately downward, also recharging the RGA. From the plant site, groundwater flows generally northward in the RGA toward the Ohio River, the local base level for the system.

Ecological Resources

Vegetation

Much of the Paducah Site has been impacted by human activity. Vegetation communities on the reservation are indicative of old field succession (e.g., grassy fields, field scrub-shrub, and upland mixed hardwoods).

The open grassland areas, most of which are managed by WKWMA personnel, are periodically mowed or burned to maintain early successional vegetation, which is dominated by members of the Compositae family and various grasses. Management practices on the WKWMA encourage reestablishment of once common native grasses such as eastern gama grass and Indian grass. Other species commonly cultivated for wildlife forage are corn, millet, milo, and soybean (CH2M Hill 1992a).

Field scrub-shrub communities consist of sun-tolerant wooded species such as persimmon, maples, black locust, sumac, and oaks (CH2M Hill 1991a). The undergrowth may vary depending on the location of the woodlands. Wooded areas near maintained grasslands may have an undergrowth dominated by grasses; other communities may contain a thick undergrowth of shrubs, including sumac, pokeweed, honeysuckle, blackberry, and grape.

Upland mixed hardwoods contain a variety of upland and transitional species. Dominant species include oaks, shagbark and shellbark hickory, and sugarberry (CH2M Hill 1991a). Undergrowth may vary from open, with limited vegetation for more mature stands of trees, to dense undergrowth similar to that described for a scrub-shrub community.

Wildlife

Wildlife species indigenous to hardwood forests, scrub-shrub, and open grassland communities are present at the Paducah Site. Grassy fields are frequented by rabbits, mice, songbirds, and a variety of other small mammals and birds. Redwing blackbirds, killdeer, cardinals, mourning doves, bobwhite quail, meadowlarks, warblers, sparrows, and red-tailed hawks have been observed in such areas. Scrub-shrub communities support a variety of wildlife including opossums, voles, moles, raccoons, gray squirrels, killdeer, bluejays, redwing blackbirds, bluebirds, cardinals, mourning doves, shrike, warblers, turkeys, and meadowlarks. Deer, squirrels, raccoons, turkeys, songbirds, and great horned owls are found within the mature woodlands of the DOE reservation (CH2M Hill 1991a). In addition, the Ohio River serves as a major flyway for migratory birds which are occasionally seen on the Paducah Site (DOE 1995).

Amphibians and reptiles are common throughout the Paducah Site. Amphibians likely to inhabit the area include the American and Woodhouse's toads. Reptiles include the eastern box turtle and several species of snakes. Also, fish populations in Bayou and Little Bayou creeks are numerically dominated by various species of sunfish (DOE 1995).

Threatened and Endangered Species

A threatened and endangered species investigation identified federally listed, proposed, or candidate species potentially occurring at or near the Paducah Site (COE 1994). Currently, potential habitat for ten species of federal concern exists in the study area (Table 2.2). Seven of these species are listed as endangered under the Endangered Species Act, one is listed as threatened, and two are candidate species which may later be proposed for listing. All are animal species, nine of which are associated with the Ohio River. Of note, significant potential summer habitat was identified for the Indiana bat, a federally listed endangered species. However, no federally listed or candidate species have been found on DOE property at the Paducah Site. Also, no property at the Paducah Site has been designated as critical habitat in accordance with the Endangered Species Act of 1973.

Cultural Resources

In a study area of about 4860 ha (12,000 acres) in and around the Paducah Site, there are 35 sites of cultural significance recorded with the State Historic Preservation Officer and several more unrecorded sites (COE 1994). Most of these sites are prehistoric and located in the Ohio River floodplain. Six of the sites are on DOE property at PGDP. None of the sites are included in, or have been nominated to, the National Register of Historic Places although some are potentially eligible. Further assessment is needed with regard to the historical significance of PGDP facilities.

Site Program Missions

DOE has three major programs at the Paducah Site - Environmental Restoration, Waste Management, and Enrichment Facilities. The mission of the Environmental Restoration Program is to ensure that releases from past operations and waste management at the Paducah Site are investigated and that appropriate remedial action is taken for protection of human health and

the environment in accordance with the Federal Facilities Agreement (FFA) (DOE 1998). The mission of the Waste Management Program is to characterize and dispose of the legacy waste stored on-site in compliance with various Federal Facilities Compliance Agreements. The primary mission of the Enrichment Facilities Program is to maintain safe, compliant storage of the DOE depleted UF_6 inventory pending final disposition of the material and to manage facilities and grounds not leased to USEC. The environmental monitoring summarized in this report supports all three programs.

2 Environmental Compliance

Abstract

The policy of DOE and its contractors and subcontractors at the Paducah Site is to conduct operations safely and minimize the impact of operations on the environment. Protection of the public, environment, and employees is considered a responsibility of paramount importance. The Paducah Site maintains an environmental compliance program aimed at meeting all applicable requirements and minimizing impacts.

Introduction

Local, state, and federal agencies, including DOE, are responsible for enforcing environmental regulations at the Paducah Site. Principal regulating agencies are the U.S. Environmental Protection Agency (EPA) Region IV and the Kentucky Department for Environmental Protection (KDEP). These agencies issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable laws and regulations.

The EPA develops, promulgates, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by the U.S. Congress. In some instances, the EPA has delegated regulatory authority to KDEP when the Kentucky program meets or exceeds EPA requirements. Where regulatory authority is not delegated, EPA Region IV is responsible for reviewing and evaluating compliance with EPA regulations as they pertain to the Paducah Site. Table 2.1 provides a summary of the Paducah Site environmental permits maintained by DOE in 1999.

The following is a list of the major environmental laws and requirements applicable to the Paducah Site. Each is discussed in this Section.

- Resource Conservation and Recovery Act (RCRA);
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA);
- Federal Facilities Compliance (FFC) Act;
- Toxicity Characteristic Leaching Procedure (TCLP) Federal Facilities Compliance Agreement (FFCA);
- National Environmental Policy Act (NEPA);

Table 2.1 Environmental Permit Summary

Permit Type	Issuer	Expiration Date	Permit Number	Issued To
Water				
KPDES	KDOW	3/ 31/2003	KY0004049	DOE
Stormwater Point Sources	KDOW	9 /30/2002	KYR100000	DOE
Solid Waste				
Residential Landfill (closed)	KDWM	NA (closed)	073-00014	DOE
Inert Landfill (closed)	KDWM	NA (closed)	073-00015	DOE
Solid Waste Contained Landfill (construction/operation)	KDWM	11/4/2006	073-00045	DOE
RCRA				
State Hazardous Waste Management Permit	KDWM	8/19/2001	KY8890008982	DOE/BJC
Mod. 15 (8/20/99)	KDWM	8/19/2001	KY8890008982	DOE/BJC
EPA Hazardous & Solid Waste Amendments Permit	EPA	8/19/2001	KY8890008982	DOE/BJC
Mod. 6 (04/01/98)	EPA	8/19/2001	KY8890008982	DOE/BJC
Air				
Cylinder Refurbishment	KDAQ	6/10/2003	S-98-044	DOE
Vortec	KDAQ	7/15/2001	S-96-239	DOE

- National Historic Preservation Act (NHPA);
- Endangered Species Act;
- Executive Order 11988, "Floodplain Management";
- Executive Order 11990, "Protection of Wetlands";
- Farmland Protection Policy Act;
- Clean Water Act (CWA);
- Toxic Substances Control Act (TSCA);
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA);
- Emergency Planning and Community Right-To-Know Act (EPCRA);
- Clean Air Act (CAA); and
- Atomic Energy Act.

Compliance Activities

Resource Conservation and Recovery Act

RCRA establishes regulatory standards for the identification, treatment, storage, and disposal of hazardous waste. Waste generators must follow specific requirements outlined in RCRA regulations for handling hazardous wastes. Owners and operators of hazardous waste treatment, storage, and disposal facilities are required to obtain operating and closure permits for hazardous waste treatment, storage, and disposal activities. Paducah generates both hazardous waste and mixed waste (i.e., hazardous waste mixed with radionuclides) and operates four permitted hazardous waste storage and treatment facilities.

RCRA Permit

RCRA Part A and Part B permit applications for storage and treatment of hazardous wastes were initially submitted for the Paducah Site in the late 1980s. At that time, the

EPA had authorized the Commonwealth of Kentucky to exclusively administer the RCRA base program for treatment, storage, and disposal units but had not given the authorization to administer the 1984 Hazardous and Solid Waste Amendments (HSWA) provisions. Therefore, a permit application was submitted to both the EPA and Kentucky Division of Waste Management (KDWM) for treatment and storage of hazardous wastes. On July 16, 1991, a 10-year RCRA permit (No. KY8890008982) was issued by KDWM and EPA to DOE as owner and operator and DOE's prime contractor as cooperator (currently Bechtel Jacobs Company LLC). This RCRA permit consists of two individual permits - a hazardous waste management permit administered by the Commonwealth of Kentucky and a HSWA permit administered by the EPA. The hazardous waste management permit issued by the Commonwealth of Kentucky contains regulatory provisions for treatment, storage, and disposal activities at PGDP, authorized under the RCRA base program (pre-HSWA), as well as HSWA provisions. The EPA HSWA permit addresses only the provisions of the HSWA, which include corrective actions for solid waste management units (SWMUs), air emissions, and the land disposal restrictions. In 1996, Kentucky received authorization to administer the HSWA provisions in lieu of EPA. Even though the state is authorized, the EPA's portion of the RCRA permit will remain in effect until it expires (August 19, 2001) or is rescinded. Therefore, the Paducah Site still has dual requirements for corrective actions under state and federal authority.

As part of the corrective action requirements, the RCRA permit's schedule of compliance requires DOE to develop and implement a RCRA facility investigation (RFI) work plan for SWMUs and areas of concern. DOE has submitted RFI work plans to the EPA and the KDWM in accordance with the time frames specified in the schedule of compliance. These RFI work plans are described in further detail in the section on CERCLA activities.

Modifications to the RCRA Permit

Since issuance the KDWM Hazardous Waste Management portion of the RCRA permit in 1991, 15 permit modifications have been approved. Modification 15 was approved in 1999. This major modification allows the Paducah Site to perform treatment in containers utilizing neutralization, oxidation/reduction, and stabilization techniques.

RCRA Closure Activities

No RCRA closure activities occurred in 1999.

RCRA Notices of Violation

KDWM performed a compliance evaluation inspection in September 1999. No notices of violation (NOVs) were issued from that inspection. However, the Paducah Site received an NOV in September 1999 following self-reporting of a noncompliance. The noncompliance reported was the result of work being performed in a SWMU without approval from KDWM. There were no fines or penalties associated with this NOV. No other NOVs were received during 1999.

Land Disposal Restrictions

Hazardous waste is subject to the land disposal restriction storage prohibition which permits storage only for accumulation of sufficient quantities of hazardous waste to facilitate proper treatment, recycling, or disposal. Hazardous wastes are not to be stored for more than one year. The Paducah Site generates mostly mixed waste, which is a combination of hazardous waste and radioactive waste. Nationally, there are very limited opportunities for treatment and disposal of mixed waste. Therefore, the Paducah Site stores most of the mixed waste that is generated for

longer than one year. Storage of waste for this purpose (lack of treatment and disposal options) does not comply with land disposal restriction regulations. If not for the radioactive constituents, this waste would not pose a compliance problem for the site, as there would be treatment and disposal options readily available. Consequently, on June 30, 1992, DOE entered into an FFCA with EPA Region IV to regulate the treatment and storage of land disposal restriction mixed waste at the Paducah Site. On April 13, 1998, EPA Region IV released DOE from the FFCA, and allowed KDWM to regulate mixed waste under the FFC Act.

Land Disposal Restrictions NOVs

No NOVs were received in 1999.

Toxicity Characteristic Leaching Procedure FFCA

The Paducah Site has generated a significant volume of waste materials that are stored on-site. A large quantity of this waste was generated, characterized, and placed in storage before September 25, 1990. At that time, characterization required utilizing the Extraction Procedure for toxicity. On September 25, 1990, a new regulation became effective replacing the Extraction Procedure for toxicity with the Toxicity Characteristic Leaching Procedure (TCLP). Since the accumulated wastes had not been characterized under the new toxicity characteristic regulations, DOE needed revised characterization data for these wastes by the new protocol.

On March 26, 1992, EPA Region IV and DOE entered into a TCLP FFCA concerning the regulatory status of these wastes. The TCLP FFCA requires the Paducah Site to identify those solid wastes that are not being managed in RCRA-regulated units and that have not been characterized under the TCLP test method. Additionally, the FFCA requires the Paducah Site to provide a schedule for TCLP characterization of the identified waste.

In response to the FFCA, the Paducah Site submitted an implementation plan that establishes a general framework for compliance with the requirements of the FFCA. The implementation plan establishes priorities for the characterization program and the nature of the data to be collected, and includes a schedule for TCLP characterization of the identified waste. The primary characterization objective is the acquisition of sufficient data to safely handle the waste and provide for determination of its status under RCRA. Characterization of the waste with respect to PCB and radionuclide concentrations is the second objective. The final characterization objective is the collection of data related to treatment and/or disposal of the waste.

A three-phase program for accomplishing the goals of the plan is underway. Phase I activities consist of data compilation and waste prioritization. Phase II involves identification of discrete waste streams and development of characterization plans. The final phase of the program includes the development of sampling and analysis plans, field sampling, and data reporting.

Phases I and II of the program have been completed. Phase III is now being carried out on a waste stream basis. The characterization plans developed during Phase II are used to guide the development of the sampling and analysis plans for the discrete waste streams. Field activities are underway to characterize the discrete waste streams. Characterization completion is set for December 2000.

TCLP FFCA NOVs

No NOVs were received during 1999.

Federal Facilities Compliance Act

The FFC Act was enacted in October 1992. This act waived the immunity from fines and penalties that had existed for federal facilities for violations of hazardous waste management as defined by RCRA. As a result of the complex issues and problems associated with mixed chemical hazardous and radioactive waste (mixed waste) and the lack of treatment and disposal capacity, the FFC Act allowed a three-year extension for DOE facilities to prepare schedules and plans on how they would manage their mixed waste in compliance with applicable RCRA regulations. The three-year waiver can be extended if (1) a mixed waste treatment plan and compliance schedule are approved by the appropriate agency, (2) an implementing order with that agency is signed, and (3) adherence to the plan and implementing order are maintained by the facility.

To facilitate compliance with the FFC Act and address the myriad of complex issues involved, the Paducah Site, along with 48 other DOE sites, began a four-phase approach. The first phase consisted of gathering required information and submitting to the EPA and state agencies an inventory of mixed wastes (mixed waste inventory report), including information pertaining to characterization and waste generation volumes. The second phase involved the development of a Conceptual Site Treatment Plan (CSTP). The plan included investigation of the existing treatment capacity for facility wastes and, where there was no existing capacity, procurement of information on potential treatment technologies or options that could be employed to meet operation requirements. The Paducah Site submitted the CSTP in October 1993. The third phase expanded on the information in the CSTP to identify treatment options that are preferred both environmentally and economically. The information gathered by the ongoing waste characterization program and the technology evaluation and development program outlined in the CSTP formed the basis for the Draft Site Treatment Plan (DSTP), which was submitted to the regulators in August 1994. The fourth phase combined the preferred treatment options from the DSTP with regulator and stakeholder comments and the overall DOE complex picture to formulate a Proposed Site Treatment Plan (PSTP). This PSTP was submitted to the regulators March 31, 1995, and provides details on how and where Paducah Site mixed waste is to be treated. On October 3, 1995, KDWM issued a Unilateral Order and the Site Treatment Plan for the Paducah Site. The Paducah Site has complied with the FFC Act and Site Treatment Plan since issuance.

FFC Act NOVs

No NOVs were received during 1999.

Solid Waste Management Compliance

The Paducah Site disposes of a portion of its solid waste at its on-site contained landfill facility, C-746-U. Construction of the C-746-U landfill began in 1995 and was completed in 1996. The operation permit was received from KDWM in November 1996. Disposal of waste at the landfill began in February 1997. All wastestreams disposed of at the contained landfill go through a wastestream certification process prior to disposal.

Office waste generated by DOE and its contractors (generated at the plant site) is taken off-site for disposal. Off-site disposal of the office waste is provided by Liquid Waste Disposal at Calvert City, Kentucky.

Solid Waste Management Compliance NOVs

No NOVs were received in 1999.

Comprehensive Environmental Response, Compensation, and Liability Act

On May 31, 1994, the Paducah Site was placed on the EPA National Priorities List (NPL), a list of sites across the nation designated by EPA as a high priority for site remediation. The EPA uses the Hazard Ranking System to determine which sites should be included on the NPL. A site is eligible for the NPL if it ranks 28.5 on the system; the Paducah Site ranked 56.9. Being placed on the NPL means DOE must follow the cleanup requirements of CERCLA.

Section 120 of CERCLA requires federal facilities on the NPL to enter into a federal facilities agreement (FFA), also referred to as an interagency agreement, with the appropriate regulatory agencies. The FFA, which was signed February 13, 1998, serves as documentation for remediation of the Paducah Site and coordinates CERCLA remedial action requirements with RCRA corrective action requirements specified in the RCRA permits. Upon signature of the FFA, the parties agreed to terminate the CERCLA ACO because those activities can be continued under the FFA. Under the FFA, DOE is required to submit an annual Site Management Plan (SMP) to EPA and KDEP. The plan summarizes the remediation work completed to date, outlines remedial priorities, and contains schedules for completing future work. The SMP is submitted to the regulators annually in November to update the enforceable milestones and include any new strategic approaches.

The Agency for Toxic Substances and Disease Registry (ATSDR), based in Atlanta, Georgia, is part of the U.S. Public Health Service. As required by CERCLA, the agency conducts public health assessments of hazardous waste sites listed or proposed for listing on the NPL. Representatives from the ATSDR made their initial site visit to Paducah in May 1994 to assign a ranking to the site for priority in scheduling the health assessment. A “B” ranking was assigned to Paducah, which is the second highest priority. The ranking was based on groundwater contamination, associated with the plant, that had affected several off-site wells. The ATSDR is aware of the actions the site has taken since 1988 to remove the risk of drinking and using this contaminated water.

In 1995, the ATSDR visited the Paducah Site to initiate a public health assessment (PHA). The PHA was scheduled to be issued in September of 2000.

CERCLA Reportable Quantities

There were no spills of a CERCLA reportable quantity at the Paducah Site in 1999.

CERCLA NOVs

No CERCLA NOVs were received in 1999.

Underground Storage Tanks

Underground storage tank systems (USTs) at the Paducah Site have been used to store petroleum products, such as gasoline, diesel fuel, and waste oil. These USTs are regulated under RCRA Subtitle I (40 CFR Part 280) and Kentucky UST regulations (401 KAR Chapter 42), or are exempt from specific UST regulations.

DOE is responsible for 14 of the 16 site USTs that have been reported to KDWM in accordance with regulatory notification requirements. Of DOE’s 14 USTs, none are currently in use - three have been removed from the ground, eight have been filled in place with inert material, one was abandoned in place, and two were determined not to exist. As of the end of 1999, only three of DOE’s USTs had yet to meet all regulatory closure requirements.

Closure activities for USTs continued in 1999 in order to achieve permanent ("clean") closure. Activities included submittal to KDWM of various Closure Assessment Reports and Classification Guides. Soils at two UST sites were resampled in accordance with an approved Alternative Sampling Plan. In 1999, correspondence was received from KDWM related to several of DOE's USTs and permanent closure was acknowledged for four of the USTs. Closure activities for USTs continued into 2000.

UST Program NOVs

No UST NOVs were received in 1999.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) provides a means to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. Compliance with NEPA, as administered by DOE's NEPA Implementing Procedures (10 CFR 1021) and Council on Environmental Quality Regulations (40 CFR 1500–1508), ensures that consideration is given to environmental values and factors in federal planning and decision making. In accordance with 10 CFR 1021, the Paducah Site conducts NEPA reviews for proposed actions and determines if any proposal requires preparation of an environmental impact statement (EIS), requires preparation of an environmental assessment (EA), or is categorically excluded (CX) from preparation of either an EIS or an EA. The Paducah Site maintains records for all NEPA reviews.

In accordance with the 1994 DOE Secretarial Policy Statement on NEPA, preparation of separate NEPA documents for environmental restoration activities conducted under CERCLA is no longer required. Instead, DOE CERCLA documents now incorporate NEPA values. Actions conducted under CERCLA are discussed in the environmental restoration sections of this report.

In 1999, the DOE Oak Ridge Operations Office determined that five actions at the Paducah Site met the criteria for CX from further NEPA review. Four other activities were determined to be within the scope of previously approved CXs. In addition, numerous minor activities were within the scope of the previously approved categorical exclusions for routine maintenance, small-scale facility modifications, and site characterization. The Paducah DOE Site Office and the DOE Oak Ridge Operations Office NEPA Compliance Officer approve and monitor the internal applications of previously approved CX determinations.

DOE continued preparation of an EA for the treatment of mixed wastes at the Paducah Site using the Vortec vitrification system. A draft of the EA was issued for a second public review in 1999.

In 1999, DOE also completed the Programmatic EIS for management of depleted uranium hexafluoride (DUF_6). The Record of Decision (ROD) documents the decision to convert the DUF_6 to uranium oxide and uranium metal.

NEPA NOVs

No NOVs were received in 1999.

National Historic Preservation Act

The National Historic Preservation Act (NHPA) of 1966 is the primary law governing federal agencies' responsibility for identifying and protecting historic properties (cultural resources included in, or eligible for inclusion in, the National Register of Historic Places). There are currently no historic properties at the Paducah Site in the National Register of Historic

Places, although there is a potential for eligible historic properties. Therefore, each proposed project is assessed to determine if there are any historic properties present and whether they may be affected. In making these determinations, DOE consults with the State Historic Preservation Officer (SHPO) as required by Section 106 of the NHPA

In accordance with 36 CFR 800.13, DOE is in the process of developing an optional NHPA compliance strategy based on a Programmatic Agreement between DOE, the Advisory Council on Historic Preservation, and the SHPO. In April 1997, a draft Programmatic Agreement was submitted to the SHPO for approval. The draft Programmatic Agreement provides for a more comprehensive cultural resources program and requires a survey to identify significant historical properties and development of a Cultural Resources Management Plan. The draft Programmatic Agreement is still under review by the SHPO.

In 1999, no activities were conducted which adversely affected historic properties.

NHPA NOVs

No NOVs were received in 1999.

Endangered Species Act

The Endangered Species Act of 1973, as amended, provides for the designation and protection of endangered and threatened animals and plants. The act also serves to protect ecosystems on which such species depend. At the Paducah Site, proposed projects are reviewed, in conjunction with NEPA project reviews, to determine if activities have the potential to impact these species. If necessary, project-specific field surveys are performed to identify threatened and endangered species and their habitats, and mitigating measures are designed as needed. When appropriate, DOE initiates consultation with the U.S. Fish and Wildlife Service prior to implementing a proposed project.

Table 2.2 lists 10 federally-listed, proposed, or candidate species that have been identified as potentially occurring at or near the Paducah Site. Project NEPA reviews and associated field surveys indicated that in 1999, DOE projects at the Paducah Site did not directly impact any of these 10 species. Potential habitats of these species were also not significantly impacted.

Endangered Species Act NOVs

No NOVs were received in 1999.

Floodplain/Wetlands Environmental Review Requirements

Title 10, Part 1022 of the *Code of Federal Regulations* (10 CFR Part 1022) establishes procedures for compliance with Executive Order 11988, “Floodplain Management,” and Executive Order 11990, “Protection of Wetlands.” Activities (other than routine maintenance) proposed within 100-year floodplains or in wetlands first require that a notice of involvement be published in the *Federal Register*. DOE must then prepare a floodplain or wetlands assessment that evaluates potential impacts on the floodplains or wetlands and considers alternatives to avoid or lessen impacts. For floodplains, a floodplain statement of findings summarizing the floodplain assessment must be published in the *Federal Register* for public comment at least 15 days before beginning the project. DOE activities in “waters of the United States,” which include wetlands, are likely to be subject to additional Clean Water Act permit requirements administered by the U.S. Army Corps of Engineers (COE) and may require water quality certification from KDEP.

Table 2.2 Federally Listed, Proposed, and Candidate Species Potentially Occurring Within the Paducah Site Study Area in 1999[a]

Common Name	Scientific Name	Endangered Species Act Status
Indiana Bat	*Myotis sodalis*	Listed Endangered
Interior Least Tern	*Sterna antillarum athalassos*	Listed Endangered
Pink Mucket	*Lampsilis abrupta*	Listed Endangered
Ring Pink	*Obovaria retusa*	Listed Endangered
Orange-footed Pearly Mussel	*Plethobasus cooperianus*	Listed Endangered
Fat Pocketbook	*Potamilus capax*	Listed Endangered
Tubercled-blossom Pearly Mussel	*Epioblasma torulosa torulosa*	Listed Endangered
Bald Eagle	*Haliaeetus leucocephalus*	Listed Threatened
Sturgeon Chub	*Macrhybopsis gelida*	Candidate
Sicklefin Chub	*Macrhybopsis meeki*	Candidate

[a] All of the above species are discussed in *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky, Volume III*, U. S. Army Corps of Engineers Nashville District, May 1994. Note that the study area encompasses 11,719 acres and extends to include the Ohio River, which is over three miles north of the DOE reservation. None of these species has been reported as sighted on the DOE reservation although potential summer habitat exists there for the Indiana bat. No critical habitat for any of these species has been designated anywhere in the study area.

In 1999, no floodplain or wetlands assessments were prepared or approved. Also, no floodplain or wetlands notices of involvement were published in the *Federal Register* for the Paducah Site. In addition, DOE did not apply for any individual permits from COE or for any water quality certifications from the state. Some DOE projects were authorized through the COE nationwide permit program for activities involving waters of the United States.

DOE activities did not result in significant impacts to floodplains or wetlands at the Paducah Site in 1999.

Floodplain/Wetlands Environmental Review Requirements NOVs

No NOVs were received in 1999.

Farmland Protection Policy Act

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. The Farmland Protection Policy Act of 1981 requires federal agencies to consider the effects of their proposed actions on prime farmland and consider any alternatives that would lessen impacts. When required, prime farmland surveys are conducted, and DOE consults with the U. S. Department of Agriculture Natural Resources Conservation Service, formerly the Soil Conservation Service. If conversion of prime farmland is anticipated, a Farmland Conversion Impact Rating form is completed and submitted to the Natural Resources Conservation Service. No Farmland Conversion Impact Rating forms were submitted to the Natural Resources Conservation Service in 1999.

DOE activities did not result in conversion of any prime farmland in 1999.

Farmland Protection Policy Act NOVs

No NOVs were received in 1999.

Clean Water Act

The Clean Water Act (CWA) was established primarily through the passage of the Federal Water Pollution Control Act Amendments of 1972. The CWA established four major programs for control of water pollution: (1) a permit program regulating point-source discharges into "waters of the U.S.," (2) a program to control and prevent spills of oil and hazardous substances, (3) a program to regulate discharges of dredge and fill materials into "waters of the U.S.," and (4) a program to provide financial assistance for construction of publicly owned sewage treatment works. The Paducah Site is primarily affected by the regulations for discharges of dredge and fill materials (see previous subsection on Floodplain/ Wetlands Environmental Review Requirements) and for point-source discharges regulated under the Kentucky Pollutant Discharge Elimination System (KPDES).

Kentucky Pollutant Discharge Elimination System

The CWA applied during 1999 to all nonradiological DOE discharges to "waters of the U.S.." At the Paducah Site, the regulations are applied through issuance of a Kentucky Pollutant Discharge Elimination System (KPDES) permit for effluent discharges to Bayou and Little Bayou creeks. The Kentucky Division of Water (KDOW) issued KPDES Permit No. KY0004049 to the Paducah Site. This permit became effective April 1, 1998, and is enforced by the KDOW. The new KPDES permit calls for biological monitoring as an indicator of discharge related effects in the receiving stream.

KPDES Permit No. KY0004049 applies to four outfalls: 001, 015, 017, and 019. Outfall 001 had two permit exceedences during 1999. Both exceedences were due to chronic toxicity. Testing indicated that a pathogen in the C-616 lagoon was responsible for the toxicity found in Outfall 001. No exceedences of effluent limits occurred at Outfall 015 which is a rainfall dependent outfall. Three permit exceedences occurred at Outfall 017 which contains runoff from DOE DUF_6 cylinder storage yards. All three exceedences were due to acute toxicity, most likely related to zinc from paint associated with newly painted DUF_6 cylinders. No exceedences of effluent limits occurred at the C-746-U landfill outfall (Outfall 019). The toxicity problems associated with Outfalls 001 and 017 are discussed in detail in the subsections below and in Section 7.

Toxicity at Outfall 001

As a result of quarterly routine compliance sampling of KPDES Outfall 001, toxicity to fathead minnows was identified in 1999. The KPDES permit requires a fathead minnow (*Pimephales promelas*) growth test and water flea (*Ceriodaphnia dubia*) life-cycle test of Outfall 001 to be conducted quarterly to evaluate wastewater toxicity. Toxicity testing of the outfall, performed the third week of July 1999, failed the fathead minnow standard established in the permit, but passed the water flea evaluation. A retest for fathead minnow toxicity was conducted within 14 days of the first failure. Results from the retest also failed the fathead minnow growth standard. Results from these toxicity evaluations were reported in the Discharge Monitoring Report (DMR) for the July-September 1999 monitoring period. Upon receipt of the toxicity results, KDOW issued a Notice of Violation (NOV) to DOE on November 23, 1999. Remedial measures identified in the NOV required DOE to immediately commence monthly toxicity monitoring at Outfall 001 and submit a Toxicity Reduction Evaluation (TRE) Plan to KDOW. A TRE Plan was submitted to KDOW on December 21, 1999.

Toxicity data from the DMR and TRE tests indicated that the failures were probably due to a fish pathogen (biological agent causing disease) in the effluent of the C-616 Full Flow Lagoon. Based on this information, simultaneous toxicity tests were conducted on untreated C-616 Lagoon effluent and effluent treated with an antibiotic to kill any pathogen present. The untreated effluent displayed the same degree of toxicity as the previous test, while the effluent treated with an antibiotic was not toxic to the fathead minnows. The evaluation provided substantial evidence that the poor survival and growth observed during July/August at Outfall 001 and C-616 Lagoon was due to a pathogen rather than a toxicant from plant operations.

Results from monthly chronic fathead minnow testing at Outfall 001 conducted in October, November, and December were negative for toxicity. This supports the theory that toxicity was linked to a pathogen that was more viable in the warm summer months.

Toxicity at Outfall 017

On December 18, 1998, routine quarterly test results from an acute toxicity test on Outfall 017 (a storm water runoff outfall located west of the PGDP access road) were received from an off-site laboratory. The sample had been collected October 6, 1998, and the acute toxicity was measured by the laboratory at 1.5 Toxicity Units acute (TUa). A retest was initiated with the next rainfall event December 21, 1998, and results of that retest were received December 28, 1998. The retest was measured at 2.2 TUa. Because the toxicity exceeded 1.2 times the TUa limit of 1.0 TUa for both samples, a TRE Plan was required by the KPDES permit. Two organisms were required to be tested per the KPDES permit: water fleas (*Ceriodaphnia dubia*) and fathead minnows (*Pimephales promelas*) . Both of the failing toxicity tests indicated no toxicity with full-strength water to the fathead minnows, but 100% toxicity to the water fleas.

In accordance with permit requirements, KDOW was verbally notified December 28, 1998, of the failure of the two consecutive tests, and by formal letter from the DOE Paducah Site Office within the five-day legal notification requirement. A draft TRE Plan was sent to KDOW January 29, 1999. Verbal approval was received February 24, 1999, accepting the TRE Plan. Also, approval was granted to test only water fleas and not fathead minnows.

Operations contained in the watershed for Outfall 017 included the cylinder storage yard operations and the nonoperational cylinder painting facility. The last cylinder was removed from the cylinder painting area September 25, 1998, and no activity occurred at that location following that date. Sampling of C-745-G cylinder yard pit, which collects water from the cylinder painting area and C-745-G cylinder storage yard, was initiated following the retest of Outfall 017. The toxicity was measured at 1.47 TUa indicating that the area draining into the C-745-G pit was toxic. With the next rainfall event on January 22, 1999, samples were taken at locations discharging into Outfall 017. Results indicated the western side of C-746-G cylinder yard was toxic and the combined discharge of cylinder yards C-746-T, S, F, H, and K were also toxic. Also, Outfall 017 continued to be toxic and the runoff from the access road near Outfall 017 was toxic. Further testing revealed that the cylinder painting area and cylinder storage yards where newly painted cylinders were stored produced toxic runoff during rainfall events.

Chemical analysis and toxicity testing was conducted on the above mentioned samples. Ethylenediaminetetraacetic acid (EDTA) tests indicated that metals were the toxic constituent in the runoff. When added to a sample, EDTA ties up the metals and makes them unavailable for uptake by biological organisms. Filtering of the samples indicated that the toxic constituent was dissolved in the toxic samples. Zinc was identified as being a contaminant that might be of concern due to its elevated presence in toxic samples. A literature search, and addition of zinc to clean water adjusted to consistent hydrogen-ion concentration (pH) and hardness, indicated

that in the toxicity tests the zinc alone was probably not toxic in the levels found in toxic samples but other factors and other chemicals present may have had a synergetic effect to produce toxicity. The TRE was carried on throughout 1999 with all evidence pointing to zinc associated with recently painted cylinders as the leading contributor to Outfall 017 toxicity. Cylinder painting was discontinued pending further evaluation.

CWA NOVs

One CWA NOV was received in 1999 as discussed in the previous subsection.

Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) was enacted in 1976 with a twofold purpose: (1) to ensure that information on the production, use, and environmental and health effects of chemical substances or mixtures are obtained by the EPA, and (2) to provide the means by which the EPA can regulate chemical substances/ mixtures.

Polychlorinated Biphenyls

The Paducah Site focuses on maintaining compliance with PCB regulations (40 CFR 761) promulgated under TSCA. Two major functions performed to ensure compliance are: (1) data tracking and documentation, and (2) providing guidance to site organizations.

The Uranium Enrichment (UE) TSCA FFCA between EPA and DOE was signed in February 1992. To meet the compliance goals at the Paducah Site, the UE TSCA FFCA is frequently revised and updated. Under this agreement, action plans have been developed and implemented for removal and disposal of large volumes of PCB material at the Paducah Site. As part of this program during 1999, 668 capacitors were removed from service. Table 2.3 shows progress of removal of capacitors in service during the year. Table 2.4 is a summary of PCB items in service at the Paducah Site at the end of 1999.

The annual PCB document, due July 1, provides details of facility activities associated with the management of PCB materials. The annual report provides details from the previous year on all PCB items that are in use, stored for reuse, generated as waste, stored for disposal, or shipped off-site for disposal. All Paducah Site UE TSCA FFCA milestones for 1999 were completed.

The facility operates equipment that contains PCB capacitors as well as transformers, electrical equipment, and other miscellaneous PCB equipment. Both radioactive and nonradioactive PCB wastes are stored on-site in storage units that meet TSCA and/or UE TSCA FFCA compliance requirements. Upon approval, nonradioactive PCBs are transported off-site to EPA-approved facilities for disposal in accordance with regulatory requirements. Radioactively contaminated PCB wastes are authorized by the UE TSCA FFCA for on-site storage beyond one year. Technology for the treatment and/or disposal of radioactively contaminated PCB wastes is being evaluated.

TSCA NOVs

No TSCA NOVs were received in 1999.

Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) regulates the manufacture, storage, and application of registered pesticides. No restricted-use pesticides are used by Paducah Site personnel. If

Table 2.3 Status of Large, High-Voltage PCB Capacitors in 1999

Building Location	Beginning Balance (1/1/99)	Capacitors Removed	New Balance (12/31/99)
C-331	69	0	69
C-333	619	206	413
C-335	46	0	46
C-337	772	462	310
Total	1506	668	838

Table 2.4 Summary of PCBs and PCB Items in Service at the End of 1999

Type	Number in Service	Volume (gal)	PCBs (kg)
PCB transformers	66	95,256	277,152
PCB-contaminated transformers	10	2,699	1.27
PCB-contaminated electrical equipment	18	5,174	1.19
PCB capacitors	838	--	--
PCB open systems[a]	3	235	10.9

[a] PCB open systems are addressed in the UE TSCA FFCA. In addition, ventilation gaskets used in various buildings throughout the Paducah Site have been determined to contain PCBs. The average PCB concentration is estimated to be 20% by weight. The total PCB content is estimated at 3840 kg in the 19,200 kg of gaskets.

application of a restricted-use pesticide at the plant were necessary for DOE activities, a certified contractor would be used. General-use pesticides are applied by plant personnel in a manner consistent with product labeling; all product warnings and cautions are strictly followed.

FIFRA NOVs

No FIFRA NOVs were received in 1999.

Emergency Planning and Community Right-To-Know Act

The Emergency Planning and Community Right-To-Know Act (EPCRA), 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. EPCRA reports are submitted to federal, state, and local authorities. Executive Order 12856, signed in August 1993, subjects all federal agencies to EPCRA. The applicable requirements of EPCRA are contained in Sections 304, 311, 312, and 313.

- Section 304 requires reporting of off-site reportable quantity releases to state and local authorities.
- Section 311 requires that either material safety data sheets (MSDSs) or lists of the hazardous chemicals for which an MSDS is required be provided to state and local authorities for emergency planning purposes.
- Section 312 requires that a hazardous chemical inventory be submitted to state and local authorities for emergency planning.
- Section 313 requires annual reporting of releases of toxic chemicals to the EPA and the state.

The Paducah Site did not have any releases that were subject to Section 304 notification requirements during 1999. No Section 311 notifications were required in 1999. The Section 312 Tier II report of inventories for 1999 included UF_6, uranium tetrafluoride (UF_4), diesel fuel, kerosene, magnesium fluoride, and PCBs associated with DOE activities. The

Paducah Site did not release any chemicals to the environment that triggered Section 313 reporting requirements.

EPCRA NOVs

No EPCRA NOVs were received in 1999.

Clean Air Act

Authority for enforcing compliance with the Clean Air Act (CAA) and subsequent amendments resides with EPA and the Kentucky Division for Air Quality (KDAQ). The Paducah Site maintains compliance with federal and state rules resulting from the CAA and its amendments.

Clean Air Act Compliance Status

The Paducah Site had two air emissions point sources in 1999. The Northwest Plume Groundwater System and the Northeast Plume Containment System are IRAs for the containment of groundwater contamination at the Paducah Site. These separate facilities remove TCE contamination from the groundwater by air stripping. At the Northwest Plume Groundwater System, the TCE-laden air passes through carbon filtration which removes much of the TCE. The air stream is then released to the atmosphere where the remaining TCE naturally breaks down. The Northwest Plume Groundwater System removed approximately 2476 pounds of TCE from the groundwater in 1999. Therefore, a portion of the TCE, a CAA hazardous air pollutant, was released to the atmosphere. Approximately 200 pounds of TCE were also released from the C-337 Cooling Tower, a part of the Northeast Plume Containment System (see Section 3).

DOE had submitted a revised air permit application for the Vortec project to KDAQ. KDAQ did not issue a permit based on the revised application in 1999.

Asbestos Program

Numerous facilities at the Paducah Site contain asbestos materials. Compliance programs for asbestos management include identification of asbestos materials, monitoring, abatement, and disposal. Procedures and program plans are maintained that delineate scope, roles, and responsibilities for maintaining compliance with EPA, Occupational Safety and Health Administration, and Kentucky regulatory requirements. No noncompliances with environmental protection standards were identified in 1999.

Radionuclide NESHAP Program

EPA and Kentucky regulate airborne emissions of radionuclides from DOE facilities via 40 CFR 61 Subpart H. Potential radionuclide sources at the Paducah Site are the Northwest Plume Groundwater System and fugitive emissions sources. The fugitive emission sources include piles of contaminated scrap metal, roads, and concrete rubble piles. DOE utilized ambient air monitoring data to verify insignificant levels of radionuclides in off-site ambient air. Ambient air data was collected at eight sites surrounding the plant in order to measure radionuclides emitted from Paducah Site sources including fugitive emissions. The Radiation/Environmental Monitoring Section of the Radiation Health and Toxic Agents Branch of the Department for Public Health of the Kentucky Cabinet for Health Services conducted ambient air monitoring during 1999. Based on observations for 1999, airborne radionuclides emitted from the Paducah Site were not detected by the ambient air monitors (KCHS no date).

Clean Air Act Amendments of 1990

The CAA Amendments of 1990 are divided into six major titles. The two titles that could affect DOE activities at the Paducah Site are: 1) Title III, Hazardous Air Pollutants, and 2) Title VI, Stratospheric Ozone Protection.

Title III, Hazardous Air Pollutants

Under Section 112, requirements shifted from a pollutant-by-pollutant, health-based regulatory approach to regulation of categories of sources using technology-based standards. Examples of hazardous air pollutants that must be regulated by the EPA include volatile organic compounds (VOCs) such as benzene, and metals such as chromium, cadmium, and manganese. The following summarizes key aspects of this legislation.

A. Pollutants and Sources Subject to Regulation

The CAA amendments completely overhauled the regulatory approach used for air toxics. Under the new approach, 189 substances are listed by Congress for regulation. Substances can be added to or deleted from the list after rule making, but EPA need not take any action with respect to these 189 substances.

Within one year of enactment, EPA was required to publish a list of all major source categories and subcategories of the listed hazardous air pollutants, such as oil refineries and chemical plants. EPA issued a list of source categories for regulation under Section 112 in July 1992. Any stationary source emitting more than 10 tons/year of any of the listed substances or 25 tons/year of any combination of the substances is considered a major source and is subject to regulation. EPA must examine other sources for regulation under an "area source" program. The Paducah Site is not a major source by virtue of its individual or total hazardous air pollutant emissions and is not currently regulated under Title III.

B. Control of Accidental Releases

Title III requires EPA to promulgate regulations to control and prevent accidental releases of regulated hazardous pollutants and extremely hazardous substances listed by EPA. Owners and operators of facilities where such substances are present in more than a threshold quantity were required to prepare risk management plans by June 21, 1999, for each listed substance used at the facility. The Paducah Site does not store or process any of the hazardous pollutants above threshold quantities and does not require a risk management plan. If DOE decides to construct and operate the Vortec project, it would exceed the threshold of 10,000 pounds of propane and, consequently, would require a risk management plan.

Title VI, Stratospheric Ozone Protection

Title VI of the 1990 amendments incorporates stratospheric ozone protection by restricting the production and consumption of chlorofluorocarbons, methyl chloroform, halons, carbon tetrachloride, and hydrochloro-fluorocarbons. Halon, methyl chloroform, chlorofluorocarbons, and carbon tetrachloride have been phased out in DOE operations. The phaseout of hydrochlorofluorocarbons is to be accomplished over a longer period, stretching out to 2020–2040. The 1990 amendments also require that production and consumption of hydrobromofluorocarbons be phased out beginning in 1996 and that methyl bromide be added to the list of controlled substances.

DOE only has refrigeration units that contain less than 50 pounds of listed substances; therefore, the only part of this regulation that applies to the Paducah Site is the requirement to control refrigerants from leaking systems and

maintain records of systems disposed. DOE has implemented these controls and a record keeping system.

CAA NOVs

No CAA NOVs were received in 1999.

Kentucky/DOE Agreement in Principle

The Kentucky Agreement in Principle (AIP) reflects the understanding and commitments between DOE and the Commonwealth of Kentucky regarding DOE's provision to provide Kentucky with technical and financial support for environmental oversight, surveillance, remediation, and emergency response activities. The goal of the AIP is to maintain an independent, impartial, and qualified assessment of the potential environmental impacts from present and future DOE activities at the Paducah Site. The AIP is intended to support non-regulatory activities whereas the FFA covers regulatory authority. The AIP includes a grant to support the Commonwealth of Kentucky in conducting independent monitoring and sampling, both on-site and off-site, and to provide support in a number of emergency response planning initiatives including cooperative planning, conducting joint training exercises, and developing public information regarding preparedness activities. The AIP is negotiated on a five-year interval. The AIP's second five-year agreement became effective January 1, 1997.

Assessments

Paducah Site environmental management programs are overseen by several organizations, both inside and outside the DOE complex. Each year, numerous appraisals, audits, and surveillances of various aspects of the environmental compliance program are conducted. Table 2.5 contains a summary of the assessments conducted in 1999.

Table 2.5 Environmental Compliance Program Assessments at the Paducah Site in 1999

Date	Auditor	Description
February 4	Bechtel Jacobs Company	Quarterly Inspection of the DOE KPDES Outfalls.
April 22	KDWM	Solid Waste Inspection of the C-746-U Solid Waste Contained Landfill.
April 26	AIP Personnel	Split Sampling of Well 20.
April 27	Environmental Services Subcontractor (ESS)	C-746-U Landfill Operations, KPDES Outfalls.
April 28	DOE	Groundwater Program.
May 30	ESS	Northwest Groundwater Treatment System
June 4	Bechtel Jacobs Company	UST Inspections.
June 9	KDWM	Solid Waste Inspection at C-746-U Solid Waste Contained Landfill.
June 30	ESS	Waste Management Operations (Training, Inspections, Manifests).
July 21	KDWM	Annual Inspection of the C-404 Hazardous Waste Landfill.
July 30	ESS	Cylinder Yard Construction, Cylinder Painting Areas, Waste Storage Areas
August 20	DOE Headquarters	DOE Office of Oversight Investigation of the False Claims Lawsuit, Phase I Back to 1990.
August 31	ESS	TSCA Storage Operations
September 3	DOE	EH Investigation (Phase I) 1990 - Present Activities.
September 24	ESS	Lasagna Operations
September 29	KDWM/KDAQ	KDWM/KDAQ Inspection of C-746-S&T Landfill, Cylinder Painting Operations, and C-637 Cooling Tower (NE Pump/Treat Operations).
October 6	KDWM	RCRA Inspection.
October 12	ESS	Sediment Controls, C-746-K Landfill
November 10	Independent RadCon Peer Review Panel	Radiological Control Program at PGDP, PORTS, ETTP, ORNL, and Y-12.
November 11	ESS	Underground Storage Tanks and North Cylinder Yard Construction
December 9	Bechtel Jacobs Company	North/South Diversion Ditch Sampling and Characterization.
December 9	ESS	C-746-U Solid Waste Landfill Boundary Identification Markers.
December 10	DOE	DOE Investigation - Pre-1990 s Events.

3 Environmental Program Information

Abstract

Environmental monitoring, environmental restoration, waste management, and UF_6 cylinder management activities occur at the Paducah Site. Several programs are conducted to inform the public about these activities.

Environmental Monitoring Program

The environmental monitoring program at the Paducah Site consists of effluent monitoring and environmental surveillance. Requirements for routine environmental monitoring programs were established to measure and monitor effluents from DOE operations and to maintain surveillance on the effects of those operations on the environment and public health through measurement, monitoring, and calculation. The environmental monitoring program is also intended to demonstrate that DOE operations at the Paducah Site comply with DOE orders and applicable federal, state, and local regulations. The environmental monitoring program is documented in the site Environmental Monitoring Plan in accordance with DOE Order 5400.1, General Environmental Protection Program. The results of this program are discussed in detail in subsequent sections of this ASER.

Before the DOE/USEC transition (described in Section 1), DOE's primary mission at the Paducah Site consisted of enriching uranium. However, since the transition on July 1, 1993, DOE's mission at the site has been focused on environmental restoration, DUF_6 cylinder management, and waste management. This change in mission has also changed the direction and emphasis of the environmental monitoring program. In November 1995, the site Environmental Monitoring Plan was reissued to address DOE operations exclusively. The Environmental Monitoring Plan is reviewed annually and updated at least every three years. Data Quality Objective (DQO) sessions were held during November and December of 1999 in order to determine if additional monitoring or changes to the environmental monitoring program were needed.

Environmental Restoration Program

The goal of the Environmental Restoration Program is to ensure that releases from past

operations and waste management activities are investigated and that appropriate remedial action is taken for the protection of human health and the environment. In May 1994, the PGDP was added to EPA's National Priorities List (NPL) of the nation's hazardous waste sites that most require cleanup. Two federal laws, the RCRA and CERCLA, are the dominant regulatory drivers for environmental restoration activities at the Paducah Site. RCRA sets the standards for managing hazardous waste and requires permits to be obtained for DOE facilities that treat, store, or dispose of hazardous waste and requires assessment and cleanup of hazardous waste releases at facilities. CERCLA addresses uncontrolled releases of hazardous substances and requires cleanup of inactive waste sites.

Background

In July 1988, the Kentucky Radiation Control Branch, in conjunction with the Purchase District Health Department, sampled several residential groundwater wells north of the plant in response to concerns from a local citizen regarding the quality of water in a private well. Subsequent analyses of these samples revealed elevated gross beta levels, indicative of possible radionuclide contamination. On August 9, 1988, these results were reported to the Paducah Site, which responded by sampling several private groundwater wells adjacent to the site on August 10, 1988. Upon analysis, some of the samples collected contained elevated levels of both trichloroethylene (TCE) and technetium-99 (^{99}Tc). In response, DOE immediately instituted the following response actions:

- provided a temporary alternate water supply to affected residences,
- sampled surrounding residential wells to assess the extent of contamination,
- began the extension of the municipal water line to affected residences as a long-term source of water, and
- began routine sampling of residential wells around the Paducah Site.

Following the initial response actions, DOE and EPA entered into an administrative consent order (ACO) in August 1988 under Sections 104 and 106 of CERCLA. The major requirements of the ACO include monitoring of residential wells potentially affected by contamination, providing alternative drinking water supplies to residents with contaminated wells, and investigation of the nature and extent of off-site contamination. Pursuant to the ACO, DOE continued routine sampling of residential wells and initiated a two-phase site investigation to identify the nature and extent of off-site contamination at the Paducah Site. Phase I of the site investigation, from summer 1989 to March 1991, evaluated the extent of off-site contamination at the Paducah Site through extensive groundwater monitoring and surface water sampling. Results of the Phase I activities are reported in *Results of the Site Investigation, Phase I Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M Hill 1991b). Phase II of the site investigation, from November 1990 to October 1991, focused on identification and characterization of on-site sources contributing to off-site contamination, determined the level of risk to human health and the environment from exposure to contaminated media and biota, and developed an initial list of remedial alternatives. Results are reported in *Results of the Site Investigation, Phase II Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M Hill 1992a). The principal findings of the site investigation are as follows:

- TCE and ^{99}Tc were identified as the primary contaminants in off-site groundwater at the Paducah Site.
- A northwest and a northeast groundwater plume extending off-site were delineated.
- Polychlorinated biphenyls (PCBs) and radionuclides were identified as the primary contaminants detected in surface water and sediment in outfalls, ditches, and creeks around the Paducah Site.

- Several on-site sources were identified as potential contributors to off-site contamination.

Risks to human health and the environment from exposure to contamination originating at the Paducah Site were reported in *Results of the Public Health and Ecological Assessment, Phase II at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M Hill 1992b). This report used data collected during the site investigation to quantitatively assess risks to human health and to qualitatively assess risks to the environment. A range of preliminary alternatives that could be used to address the contamination was also developed as part of the ACO activities. This information was presented in *Summary of Alternatives for Remediation of Off-Site Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (Draft) (SAIC 1991). Upon completion of the Phase II activities and in response to the risks identified in the public health and ecological assessment, the Paducah Site developed and implemented several interim remedial actions designed to prevent further migration of contaminants and to reduce risks to human health and the environment. The actions targeted certain on-site sources and the off-site contamination associated with groundwater and surface water.

As part of the routine residential sampling that began when off-site contamination was discovered, DOE established a water policy. This policy states that in the event contamination originating from the Paducah Site is detected above plant-action levels, which are established at the analytical laboratory detection limits of 25 picoCuries per liter (pCi/L) for ^{99}Tc and 1 part per billion (ppb) for TCE, a response would be initiated by the Paducah Site. Accordingly, residents would be notified immediately as would state and EPA officials. Alternative water supplies would be provided through connection to the municipal water system, or in the event of a time lapse between discovery and the ability to complete connections, bottled water would be made available. DOE pays the cost of installation of water systems and the monthly charges for water service to residents with contaminated wells.

DOE modified this water policy to include provisions to extend a municipal water line to the entire area potentially affected by groundwater contamination originating from the Paducah Site. All residents within the affected area, regardless of whether or not their wells were contaminated, were given the option to receive municipal water at DOE expense. Of the 83 eligible property owners, 73 signed agreements to accept the water provision and not to use or dig wells on their property for human consumption. DOE also provides municipal water to new residents and some new businesses. A five-year review of the water policy was prepared in November 1997; however, issuance was delayed into 1998 by changes in the regulatory strategy. The five-year review was issued in 1999.

Because of the extension of the municipal water line, the new water policy allows reduction in the number and frequency of residential wells sampled routinely. This modification provides for a more cost-effective allocation of well-sampling resources. Through the strategic placement of additional monitoring wells, the modification also allows more accurate data on location and movement of contaminated groundwater.

The most significant interim action taken under the ACO, documented in *Technical Memorandum for Interim Remedial Action of the Northwest Plume* (DOE/OR/1031&D2), included groundwater extraction and treatment to reduce the spread of contamination from the source and high concentration areas of the Northwest Plume. The *Proposed Plan for Interim Remedial Action of the Northwest Plume* (DOE/OR/06-1127&D2), which summarizes the interim alternatives, was approved by EPA April 15, 1993. The *Record of Decision for Interim Remedial Action of the Northwest Plume* (DOE/OR/06-1143&D2) was signed by DOE on July 15, 1993, and by EPA on July 22, 1993. Construction of the interim action (the C-612

Northwest Plume Groundwater System) was completed and operational August 28, 1995.

A second groundwater remediation action, the *Record of Decision (ROD) for Interim Remedial Action (IRA) at the Northeast Plume* (DOE/OR/06-1356&D2), was signed by DOE on June 13, 1995, and the EPA on June 1, 1995. The ROD called for the hydraulic containment and treatment of high concentrations of off-site TCE contamination in the Northeast Plume.

Other interim actions completed to date include the North-South Diversion Ditch, institutional controls for surface water/ditches and scrapyards, enhancement of the existing cap for Waste Area Group (WAG) 7 (C-746-K Landfill), and a removal action at WAG 17 [Area of Concern (AOC) 124]. The North-South Diversion Ditch Interim Action called for treating certain plant effluents and controlling the migration of contaminated sediment associated with the ditch. The installation of fencing/posting restricted recreational use of surface water, outfalls, and lagoons. The installation of sediment controls to mitigate surface water/sediment runoff from scrap yards has also been completed and is inspected on a monthly basis. The existing cap for the C-746-K Landfill was enhanced to reduce leachate migration from surface infiltration.

Environmental Restoration Program Activities

The Environmental Restoration Program supports remedial investigations and response actions, decontamination and decommissioning of facilities no longer in use, projects designed to demonstrate advancements in remedial technologies, and other projects related to remedial action for the protection of human health and the environment.

Operable Units

Sources of contamination are identified as solid waste management units (SWMUs) and areas of concern (AOCs). To expedite investigations, the SWMUs/AOCs are grouped together into waste area groupings (WAGs) based on specific criteria. In 1998, DOE further refined this WAG strategy and grouped the WAGs into Operable Units (OUs) based on site remedial objectives, which are explained in detail in the Paducah Site Management Plan (DOE 1998). This change is intended to maximize opportunities to benefit from regional approaches and economies of scale, and provide a better process to evaluate cumulative effects on all media. Based on these revisions, the new strategy establishes a framework for conducting five major remedial actions:

1. The Groundwater OU focuses on protection of off-site residents,
2. The Surface Water OU focuses on protection of recreational users and ecosystems,
3. The Burial Grounds OU focuses on protection of industrial workers,
4. The Surface Soils OU focuses on protection of industrial workers, and
5. The Decontamination and Decommissioning OU focuses on protection of industrial workers.

The scope of these potential operable units (OUs) includes both the suspected source areas and affected media, with data collection and decision making specifically focused on accomplishing the site remedial objectives. For example, the Groundwater OU will specifically focus efforts on addressing contaminants of concern (COCs) presenting a risk to the off-site groundwater users regardless of the media (e.g., soils, groundwater), whereas the proposed action for surface soils will have a specific focus on addressing the COCs located in soils from a 0' to 10' depth, presenting a direct-contact risk to industrial workers. However, while these

actions are intended to be focused in nature, cleanup standards selected under a specific OU should also be protective of other exposure scenarios when applicable. For example, if a groundwater COC is present within the upper 10' of soil, then the cleanup standard should not only be protective of the off-site groundwater user (off-site resident), but it should also reflect protection of an industrial worker from direct contact. In cases where the Surface Soils OU is targeting a COC to protect industrial workers from direct contact, the selected cleanup standard should also be designed to be protective of recreational users and ecosystems should off-site migration via surface runoff be a concern.

When a specific SWMU/WAG has the potential to impact multiple pathways/receptors, it may be assigned to two or more OUs. As an example, the COCs contributing to groundwater may be addressed under the Groundwater OU, whereas the surficial contamination presenting a direct contact risk to industrial workers may be addressed under the Surface Soils OU.

Upon completion of investigation for the five OUs, a study will be conducted. The scope of the Comprehensive Site-Wide OU study will include a comprehensive site-wide baseline risk assessment to evaluate any residual risk remaining at the site after completion of activities at the five initial OUs, and to evaluate the cumulative effects from all media. If the Comprehensive Site-Wide OU risk assessment concludes the actions taken to date collectively provide adequate protection to human health and the environment, a final Comprehensive Site-Wide OU Proposed Plan and ROD will be issued. These reports will be followed by a final remediation report declaring site remediation complete. In the event the Comprehensive Site-Wide OU risk assessment determines additional actions are needed, a feasibility study (FS) will be developed with the preferred alternative documented in a Proposed Plan and ROD, followed by the necessary remedial actions prior to issuing the final remediation report.

Remedial Priorities

PGDP currently contains numerous sites that are subject to the CERCLA cleanup process. The SMP establishes work priorities based on factors specified in the FFA. Under the original strategy, the WAGs were prioritized based on the following criteria:

- immediate risks,
- hot spots associated with off-site contamination,
- suspected sources of off-site contamination,
- suspected sources of on-site contamination, and
- groundwater and surface water.

While several actions have been taken to date with emphasis on “immediate risks” and “hot spots,” the Water Policy, the northwest and northeast groundwater treatment systems, and the construction of institutional controls for surface water have provided the most significant benefits. The current focus is now directed toward the sources of off-site contamination. However, as a result of the new strategy, the site priorities have been revised to reflect acceleration of groundwater and surface water to be addressed with their corresponding source areas, as opposed to being completed at the end of the process, as depicted in Figure 3.1. This change was primarily due to the fact that both groundwater and surface water serve as migration pathways to off-site receptors, and there is a strong technical and risk benefit of integrating remedial decisions for the source areas with the affected media. Also, it should be noted that should new data suggest the identification of additional site contamination posing an imminent risk or newly discovered hot spots, then additional remedial actions or interim remedial actions may be necessary. Based on these revised priorities, the available resources are then focused on the higher priority OUs. As the higher priority work is completed, or when additional resources become available, the

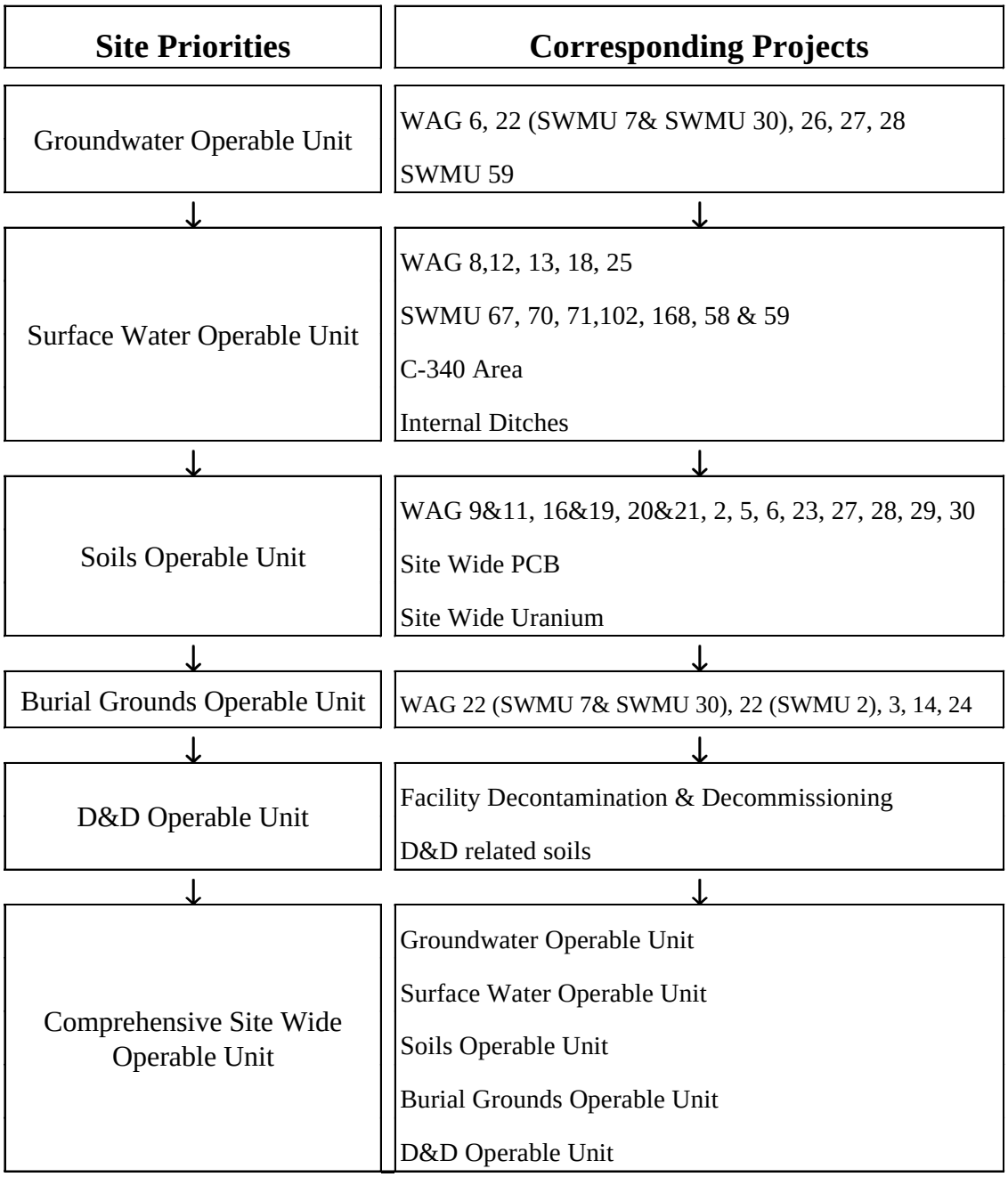

Figure 3.1 Site management plan priority and corresponding projects.

lower priority WAGs and OUs will be addressed. Site prioritization will continue to be a joint effort between all parties, including DOE, the Commonwealth of Kentucky, and EPA.

1999 Remedial Activities

Several remedial activities were conducted in 1999. The following summarizes some of the more significant accomplishments completed during that time frame:

- Completed installation and began operation of the Lasagna™ technology as the selected remedial alternative for reducing the concentration of TCE in SWMU 91.

- Submitted the Remedial Investigation (RI)/FS Work Plan for the Surface Water Operable Unit to the regulators for review and comment.

- Performed the WAG 28 and WAG 3 RIs, the WAG 8 Site Evaluation (SE), and the Data Gaps Investigation. Information concerning these four activities is summarized in the following text.

Lasagna™

In July 1998, DOE issued the *Record of Decision for Remedial Action at Solid Waste Management Unit 91 of Waste Area Group 27 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 1998). The Record of Decision (ROD) designated Lasagna™ as the selected remedial alternative for reducing the concentration of TCE in SWMU 91 to levels that would decrease the potential groundwater risk to human health and the environment at the point-of-exposure (POE).

Lasagna™ was selected as the preferred remedial alternative for the reduction of TCE in the soil at SWMU 91. The ROD states, "The primary objective of this remedial action is to reduce the level of TCE-contaminated soil, thereby reducing the potential future concentrations in groundwater that could pose a threat to human health and the environment at the POE (i.e., the DOE property boundary)." The Lasagna™ system will be operated for two years in an attempt to reduce the concentration of TCE in SWMU 91 soil from an average of 84 mg/kg to an average of less than 5.6 mg/kg. If after two years the regulatory approved cleanup level of 5.6 mg/kg has not been achieved, the system may operate an additional 12 months to achieve the cleanup levels.

Lasagna™ uses an applied direct current electric field to drive TCE-contaminated groundwater through treatment zones installed in the contaminated soil. This induced groundwater flow is called electro-osmosis. The groundwater flow induced by the direct current travels from the anode electrodes to the cathode electrode. Groundwater containing TCE is driven away from anode electrodes toward the cathode electrode and passes through a series of iron particle treatment zones installed between them. The TCE is broken down into nonhazardous compounds as it comes in contact with the iron particles in the treatment zones. Additional information about the Lasagna™ technology and its development can be found in the *Final Soil Characterization Work Plan For The Paducah Gaseous Diffusion Plant Lasagna Pilot Test In The Cylinder Drop Test Area* (MMES 1994) and the *DNAPL Site Characterization And Lasagna™ Technology Demonstration At Solid Waste Management Unit 91 Of The Paducah Gaseous Diffusion Plant, Kentucky* (LMES 1996a).

Anode electrode zones were installed generally north to south along the outer edges of the 90-ft wide treatment area. The cathode electrode zones were installed generally north to south in the middle of the treatment area. The direct current to energize the electrodes comes from a rectifier that is fed from a 480-volt alternating current supply constructed for this project. New overhead electrical utility lines, power transformers, electrical switching center, and associated accessories provide power to the Lasagna™ site. In general, treatment zones were installed at 5-ft intervals across the treatment area. However, treatment zones were installed at 2.5-ft intervals in higher concentration regions of the treatment area. When possible, electrode and treatment zones were installed to a depth of 45 ft. Plumbing was installed to recycle treated water from the cathode back to the anodes.

Installation of the Lasagna™ technology was completed in September 1999. The system is currently operational and is being monitoring for progress of remediation of SWMU 91.

WAG 28

The WAG 28 RI was initiated and completed during 1999. The primary focus of the WAG 28 investigation was groundwater samples. Soils collected adjacent to a storm drain exposed outside the boundary of SWMU 99 were found to contain PCBs, ^{99}Tc, uranium, ^{137}Cs, ^{237}Np, and ^{234}Th.

The WAG 28 RI consisted of four sites located within the eastern portion of PGDP, including three SWMUs and one AOC. The four sites were SWMU 99, the C-745 Kellogg Building Site; SWMU 193, the McGraw Construction Facilities; SWMU 194, the McGraw Construction Facilities Leach Fields; and AOC 204, a heavily vegetated area located on the eastern side of PGDP.

Table 3.1 lists the total number of samples collected at the WAG 28 SWMUs by media. Soil and water samples were collected and analyzed for VOCs, semivolatile organics (SVOAs), PCBs, metals, and radionuclides. An on-site screening of alpha, beta, and gamma activities was used to identify the samples that might require radioisotopic analysis in a fixed-base laboratory. The analyzed radioisotopes were ^{241}Am, ^{237}Np, ^{239}Pu, and $^{239/240}$Pu.

Sampling of the soils within SWMU 99 detected a limited suite of metals above screening criteria and isolated occurrences of SVOAs in the surface soils. Relatively minor concentrations of trichloroethylene (TCE) were seen in the soils and groundwater of the UCRS. Higher concentrations of TCE reflective of the Northeast Plume were observed in the RGA groundwater samples. Soils collected adjacent to a storm drain exposed outside the boundary of SWMU 99 were found to contain elevated levels of PCBs, ^{99}Tc, uranium, ^{137}Cs, ^{237}Np, and ^{234}Th.

Table 3.1 Samples Collected During WAG 28 by SWMU and Media

	Subsurface Soil	Ground-water
SWMU 99	134	72
SWMU 193	54	74
SWMU 194	21	0
AOC 204	29	8

Data collected for this investigation identified no TCE present in soils at SWMU 193. TCE is not a widespread contaminant in the RGA and McNairy at SWMU 193. The maximum concentration of TCE reported from the McNairy water samples was 42 µg/L, and the deepest penetration of TCE into the McNairy is to 32 feet below the base of the RGA. ^{99}Tc is the most widespread of the radionuclides in the groundwater at SWMU 193. The distribution and location of highest ^{99}Tc activities in the RGA closely mimics the distribution of TCE. ^{99}Tc was detected in two McNairy water samples at 145 pCi/L and 14.8 pCi/L.

Metals detected in the shallow subsurface at SWMU 194 represent both naturally occurring conditions and possible releases to the subsurface. Aluminum levels detected at the site are considered to represent naturally occurring concentrations. Cadmium, lead, and chromium that have been reported from the site may represent isolated releases to the subsurface from the leach field.

For AOC 204, TCE was noted primarily in the RGA, but not in concentrations that would indicate a nearby source. The lack of significant concentrations of TCE in the shallow subsurface does not support the presence of an on-site source for TCE at AOC 204. Radionuclides were not observed at levels of concern in either the groundwater or soils.

As part of the WAG 28 evaluation process, the impact on RGA groundwater from possible contaminant releases was investigated at SWMU 99, SWMU 193, and AOC 204. In general, it is clear that the predominant contaminants in the

surface and subsurface soils at WAG 28 are metals. This contrasts with the overwhelming and well-documented contamination in RGA and McNairy groundwater that is characterized by the presence of chlorinated alkenes and radionuclides (predominantly TCE and ^{99}Tc, respectively). These differences in the suites between the soil and groundwater-borne contaminants suggest that the areas investigated during the WAG 28 RI are not significant sources of the existing groundwater contamination. However, a range of contaminants, including metals, volatile organic compounds, and radionuclides, was detected in the soils at WAG 28, some of which appear to have the capacity to migrate to groundwater in the future.

SWMU 99 does not contain significant contaminant concentrations in either the UCRS soils or UCRS groundwater that would suggest the site is currently or will in the future become a significant contributor of contaminants to the Northeast Plume. However, elevated levels of radionuclides were discovered in shallow soils surrounding a broken drainpipe that drains the SWMU 99 area. This migration pathway, which feeds Outfall 010, may be a contributing source to contamination observed in the Northeast Plume in the underlying RGA.

Sampling of the UCRS soils during the WAG 28 RI indicates that the primary source of the contamination in the RGA groundwater at SWMU 193 does not exist at the former location of the Millwright Shop as originally believed. Moreover, TCE concentrations currently in the RGA groundwater beneath the site have decreased significantly during the last four years. This decrease in TCE concentrations in the RGA at the Millwright Shop is best attributed to migration and dispersion of the contaminated groundwater plume.

At AOC 204, relatively minor trichloroethene concentrations (<100 µg/kg) were observed in the near surface soils adjacent to Outfall 011, but higher concentrations were observed at greater depths in the borings located in the interior of the site. This evidence indicates that contaminants detected in the UCRS soils are related to the downward percolation of surface water flow in Outfall 011. This infiltration of contaminants from a losing surface water stream would appear to represent one potential source for the contaminants present in the Northeast Plume.

The results of the WAG 28 RI show that widespread contamination is not present in either the UCRS soil or the UCRS groundwater at any of the areas investigated. None of the WAG 28 sites sampled for the RI has been identified as a significant contributor of contaminants to the underlying RGA groundwater. This conclusion is based on the evaluation of the nature, extent, and concentration of contaminants found during the WAG 28 investigation, taking into account the data obtained from both previous and current rounds of sampling.

The *Remedial Investigation Report for Waste Area Grouping 28 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2000a) provides conclusions and additional information on the WAG 28 RI activities.

WAG 8

In 1999, the WAG 8 SE was initiated with 90% of the work being completed at the year's end. The goals of the WAG 8 SE were to confirm or deny the presence of contaminants at each of the WAG 8 sites, evaluate migration pathways to determine if the sites are presently sources of off-site contamination, and to determine risk from each site to on-site receptors. The focus of the SE was to collect sufficient information about surface water, surface soil, subsurface soil, and shallow groundwater contamination to support the evaluation process. The results of the SE were used to formulate recommendations concerning further actions for each site.

The WAG 8 SE consisted of five sites within the PGDP that were considered a potential source for PCBs. Four of the five sites are electrical switchyards, while the fifth site is an abandoned UF_6 conversion facility. The five sites were SWMU 82, the C-531 Electrical Switchyard; SWMU 83, the C-533 Electrical Switchyard; SWMU 84, the C-535 Electrical Switchyard; SWMU 85, the C-537 Electrical Switchyard; and C-340 Reduction and Metals Facility. Table 3.2 lists the total number of samples collected at each WAG 8 SWMU and building by media.

Soil and water samples were collected and analyzed for VOCs, SVOAs, PCBs, metals, and radionuclides. An on-site screening of alpha, beta, and gamma activities was used to identify the samples that might require radioisotopic analysis in a fixed-base laboratory. The analyzed radioisotopes were ^{241}Am, ^{237}Np, ^{239}Pu, and $^{239/240}Pu$.

Several SVOAs, radionuclides, PCBs, and dioxin/furans were detected in the surface soil samples collected from the drainage ditch at SWMU 82. Detections of PCBs, at a maximum concentration of 1,183 mg/kg, and dioxin/furans, at a maximum concentration of 25,200 picograms/gram (pg/g), represent residual contaminants from historical leaks and spills at the site. Low levels of SVOAs are known to be ubiquitous to PGDP, and radionuclides are not process-related to the electrical switchyards. No COCs were detected in the subsurface soil at SWMU 82.

Surface soil samples collected in the drainage ditches at SWMU 83 contained low concentrations of several SVOAs (maximum concentration only slightly above the method detection limit). Several metals (aluminum, beryllium, nickel, vanadium, iron, and magnesium) were detected in the subsurface at concentrations that only slightly exceeded background levels.

Several SVOAs, ^{137}Cs, PCBs, and dioxin/furans were detected in the surface soil samples collected from the drainage ditch at SWMU 84. Detections of PCBs, at a maximum concentration of 380 mg/kg, and dixoin/furans, at a maximum concentration of 6790 pg/g, represent residual contaminants from historical leaks and spills at the site. No site-derived contaminants were detected in the subsurface soil at SWMU 84.

Several SVOAs, PCBs, and dioxin/furans were detected in the surface soil samples collected from the drainage ditch at SWMU 85. Detections of PCBs, at a maximum concentration of 71 mg/kg, and dioxin/furans, at a maximum concentration of 9,180 pg/g, represent residual contaminants from historical leaks and spills at the site. No site-derived contaminants were detected in the subsurface soil at SWMU 85.

At SWMU 82, 83, 84, and 85, only a small quantity of ^{99}Tc (23.4 pCi/L, 17.4 pCi/L, 17.9 pCi/L, 16.2 pCi/L, respectively) was detected. ^{99}Tc is not a process-related contaminant at the electrical switchyard; therefore, site-derived contaminants are not being transported offsite via the storm water migration pathway. The lack of site-derived contaminants in the subsurface at each of the four SWMUs indicates the leaching of contaminants from the soil to groundwater is not a significant contaminant migration pathway.

Contamination in the C-340 Building consists of radiological and chemical contaminants remaining from the uranium metal production process previously performed in the building. Documentation pertaining to releases is not available, but it is likely that some of the process feedstock, product material, by-products, uranium metal scraps, sludges, and ancillary materials could have been carried outside the building during process spills through the building ventilation and drainage systems. Surface soils at the C-340 Building contain elevated levels of SVOAs, PCBs, dioxins/furans, metals, and radionuclides over most of the site. Polycyclic aromatic hydrocarbons (PAHs) are present at concentrations in excess of 100,000 mg/kg.

Table 3.2 Samples Collected During WAG 8 by SWMU and Media

	Subsurface Soil	Surface Water	Ground-water
SWMU 82	28	3	1
SWMU 83	24	3	3
SWMU 84	35	3	25
SWMU 85	30	3	19
C-340	38	N/A	N/A

PCBs exhibited concentrations that exceeded 500,000 mg/kg for some congeners. Radiological constituents are distributed throughout the site at a maximum activity of 2,890 pCi/g for ^{234}Th and a maximum activity of 2,740 pCi/g for ^{238}U. Aside from the radiological constituents and metals, it is not understood what processes may have taken place in the C-340 Building that would have resulted in the release of the PAHs, PCBs, or dioxin/furans. Subsurface soil-contained ^{99}Tc at an activity of 7.36 pCi/g and metals at maximum concentrations equal to or less than twice background levels. The isolated occurrences of contaminants found in the subsurface soil indicate that infiltration of groundwater is not a significant contaminant migration pathway at the C-340 Building.

The *Site Evaluation Report for Waste Area Grouping 8 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2000c) provides conclusions and additional information on WAG 8 SE activities.

WAG 3

In 1999, the WAG 3 RI was initiated with 90% of the work being completed at the year's end. The primary focus of the WAG 3 RI was to collect sufficient information about surface soil, subsurface soil, and shallow groundwater to accomplish the following:

- evaluate potential sources of contamination,
- determine if the contaminant sources are contributing to contamination already known to exist in deep groundwater or surface water,
- assess risks to human health and the environment posed by this contamination
- determine if remedial actions are required to reduce these risks, and
- support selection of an appropriate remedial action.

The WAG 3 RI consisted of 3 SWMUs within the PGDP. These sites were SWMU 4, the C-747 Contaminated Burial Cell; SWMU 5, the C-746-F Classified Burial Yard; and SWMU 6, the C-747-B Burial Yard.

Table 3.3 lists the total number of samples collected at each SWMU by media. Soil and water samples were collected and analyzed for VOCs, SVOAs, PCBs, metals, and radionuclides. An on-site screening of alpha, beta, and gamma activities was used to identify the samples that might require radioisotopic analysis in a fixed-base laboratory.

Soil sampling in SWMU 4 indicated significant levels of PCBs at depths of approximately 3 ft below ground surface (BGS), TCE and various degradation products (including vinyl chloride and cis-1,1-dichloroethene) in

Table 3.3 Samples Collected During WAG 3 by SWMU and Media

	Sediment	Subsurface Soil	Ground-water
SWMU 4	5	221	163
SWMU 5	7	55	80
SWMU 6	3	81	96

soils immediately adjacent to and under the burial cells, and various radionuclides, including the following radioisotopes: plutonium-239/240, uranium-234/235/238, neptunium-239, and radium-226. Groundwater at SWMU 4 exhibited a similar suite of contaminants in the subsurface soils in the UCRS groundwater system. Most of the contamination was also located immediately adjacent to or underneath the burial cells.

Sampling at SWMU 5 indicated isolated occurrences of metals, PCBs, pesticides, herbicides, and PAHs found in the surface, subsurface, or groundwater media. Due to security restrictions limited sampling was performed within the burial cells. The absence of any significant contaminants suggests that SWMU 5 is not currently a source of contamination.

As with SWMU 5, sampling at SWMU 6 did not indicate any significant levels of contaminants, and no trend indicating widespread contamination at the site was identified. Minimal detections of PCBs, radionuclides, and metals were detected in the soils and shallow groundwater. TCE was identified in the RGA samples at the SWMU, but this contamination is likely part of the Northwest Plume. The absence of any TCE or other VOCs in the UCRS precludes SWMU 6 as a contaminant source to the Northwest Plume.

The *Remedial Investigation Report for Waste Area Grouping 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2000d) provides conclusions and additional information on the WAG 3 RI activities.

Data Gaps

The primary objective of the Data Gaps Investigation was to collect data to determine the location of contaminant plumes migrating beyond the PGDP boundary, to decrease the uncertainty that unknown or previously undetected plumes are existing at the PGDP, and to provide additional support for a sitewide remedial action for sources contributing to off-site groundwater contamination. The Data Gaps Investigation was conducted to provide supplemental data on the Groundwater OU. The data will be incorporated into other data sets from other investigations to develop conclusions to be made.

Table 3.4 Samples Collected During Data Gaps by Media

	Subsurface Soil	Groundwater
Data Gaps	84	463

Table 3.4 lists the total number of samples collected by media. Soil and water samples were collected and analyzed for VOCs, SVOAs, PCBs, and radionuclides, as well as hydraulic and geotechnical parameters, such as hydraulic conductivity, porosity, bulk density, grain size, shear strength, and Atterberg limits of soils. An on-site screening of alpha, beta, and gamma activities was used to identify the samples that might require radioisotopic analysis in a fixed-base laboratory. The analyzed radioisotopes were ^{241}Am, ^{237}Np, ^{239}Pu, and $^{239/240}$Pu.

The *Data Report for the Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2000e) provides additional information on the Data Gaps Investigation activities.

Northwest Plume Groundwater System

The IRA of the Northwest Plume Groundwater System is documented in a ROD signed by DOE and EPA in July 1993. KDEP also concurred with the ROD. The IRA began

operations on August 28, 1995. The IRA consists of two extraction well fields with two wells each, transfer pipelines, a treatment system, and appurtenant equipment. The interim action is designed to contain the migration of the high concentration zone of the groundwater contaminant plume. Plume contaminants are TCE and ^{99}Tc.

TCE is removed by an air stripping process. The TCE is volatilized by a large volume of air that comes into contact with the contaminated groundwater during the treatment process. Activated carbon filtration beds are then used to remove the TCE, which is entrained in the air stream, before the air is released to the atmosphere. ^{99}Tc is removed by an ion exchange process.

The treatment system has extracted and treated approximately 400 million gallons of contaminated groundwater from start up through the end of 1999. The treatment system has been on-line approximately 98% of the time since startup, exceeding the goal of 85%t. The IRA has consistently met the groundwater treatment goals documented in the ROD of f5 ppb TCE and 900 pCi/L of ^{99}Tc. The groundwater, after treatment, is released through a KPDES permitted outfall. Radiological emissions from this facility are discussed in Section 4.

Northeast Plume Containment System

The IRA of the Northeast Plume was documented in a ROD signed by DOE and the EPA in June 1995. The KDEP accepted the ROD with the issuance of the Hazardous Waste Permit Modification 8 dated June 26, 1995. The IRA system consists of an extraction well field, equalization tank, transfer pump, transfer piping and required instrumentation, electrical power and appurtenances and use of the existing C-637-2A Cooling Tower at the PGDP for stripping of TCE. Characterization and construction activities were completed during December of 1996. System startup and operational testing was conducted in February 1997 with the system fully operational by February 28, 1997. The IRA began operations February 28, 1997.

System operation includes pumping groundwater contaminated with TCE from two extraction wells to an equalization tank. A transfer pump is used to pump the contaminated water from the equalization tank through a transfer line (greater than 6,000 linear feet) to the top of the C-637 Cooling Tower. The cooling tower acts as an air stripper and removes the TCE from the groundwater.

Through the end of 1999, approximately 228 million gallons of contaminated groundwater have been extracted. The system has been operational approximately 95% of the time since startup with the exception during July through September 1999 when the facility was taken off-line due to cooling tower maintenance.

Decontamination and Decommissioning

Decontamination and decommissioning (D&D) is the disposition of facilities and other structures contaminated with radiological and hazardous material. Facilities are accepted for D&D when they are no longer required to fulfill a site mission. Legacy contamination on the structure, floors, walls, and equipment constitutes a potential for release to the environment if not appropriately managed in the near term and ultimately removed. Two major facilities comprising approximately 46,450 m^2 (500,000 ft^2) have been accepted for D&D. These facilities are the C-340 Metal Reduction Plant complex, where UF_6 was converted to uranium metal and hydrogen fluoride, and the C-410 Feed Plant complex, where uranium trioxide (UO3) was converted to UF_6. Contaminants at these facilities include depleted uranium, natural uranium and transuranic radionuclides (at C-410 only), uranium tetrafluoride, polychlorinated biphenyls (PCB), asbestos, and lead paint. Activities performed during the year include surveillance and maintenance of the structures to ensure containment of residual materials,

decontamination and decommissioning project planning for future implementation and planning, and planning for the additional removal and sale of surplus fluorine-generating equipment to private industry.

Technological Demonstration

The Environmental Restoration Program actively supports demonstrating new remediation technologies that have been developed by private industry. In 1999, two demonstrations were conducted at the Northwest Plume Groundwater System involving possible improved methods for removal of ^{99}Tc from the groundwater. The 3M Company provided a test system equipped with a new, coated micropore filter designed to remove ^{99}Tc. The filters, configured in an easily removable cartridge arrangement, were tested on a groundwater side stream in the C-612Building. Results indicated a ^{99}Tc removal capacity similar to the ion exchange resin currently in use. At the time of the tests, however, the filters were not available in a size that would meet the flow requirements of the Northwest Plume Groundwater System. A second test was conducted on a new synthetic ion exchange resin developed by scientists at Oak Ridge National Laboratory. The resin is similar in function and physical characteristics to the commercial resin currently used for ^{99}Tc removal at C-612. Preliminary laboratory studies of the synthetic resin indicated ^{99}Tc removal efficiencies in excess of five times that of the commercial resin. Results from a small test column placed in the C-612 facility confirmed the laboratory test results. If the synthetic resin can be manufactured in quantities and at prices meeting the Northwest Plume Groundwater System needs, its use could result in a reduction of waste for the project.

Waste Management Program

The Paducah Site Waste Management Program directs the safe treatment, storage, and disposal of waste generated before July 1, 1993 (i.e., legacy wastes), and waste from current DOE activities. The primary objective of the program is to ensure that waste materials do not migrate into the environment. Waste managed under the program is divided into the following seven categories:

- *Low-level radioactive waste* - radioactive waste not classified as high-level or transuranic and does not contain any components regulated by RCRA or TSCA.
- *Hazardous 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.
- *Mixed waste* - waste containing both hazardous and radioactive components. Mixed waste is subject to RCRA, which governs the hazardous components, and to additional regulations that govern the radioactive components.
- *Transuranic waste* - waste that contains more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years.
- *PCB and PCB-contaminated wastes* - waste containing or contaminated with PCBs, a class of synthetic organic chemicals including 209 known isomers, each with from 1 to 10 chlorine atoms on a biphenyl ring. Under TSCA 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.
- *Asbestos waste* - asbestos-containing materials from renovation and demolition activities.

- *Sanitary/Industrial waste* - waste that is neither radioactive nor hazardous. Solid sanitary/industrial waste is basically refuse or industrial/construction debris and is disposed in landfills.

Requirements for meeting waste management regulatory objectives are varied and complex because of the variety of waste streams generated by DOE activities. The goal, however, is to comply with all current regulations while planning actions to comply with anticipated future regulations.

Compliance for waste management activities involves meeting EPA and state regulations and DOE orders. In addition to compliance with these regulations, supplemental policies are enacted for management of radioactive, hazardous, and mixed wastes. These policies include reducing the amount of wastes generated; characterizing and certifying waste before it is stored, processed, treated, or disposed; and pursuing volume reduction and use of on-site storage, when safe and cost effective, until a final disposal option is identified. Table 3.5 summarizes the major accomplishments of the Waste Management Program during 1999.

Waste Minimization / Pollution Prevention

The Pollution Prevention/Waste Minimization (PP/WM) Program at the Paducah Site provides guidance and objectives for minimizing waste generation. Guidance for the program comes from regulations promulgated by RCRA, the Pollution Prevention Act, applicable state and EPA rules, DOE Orders, and Executive Orders.

The program is striving to meet its goals with the following strategy:

- source reduction,
- segregation,
- reuse of materials, and

Table 3.5 Waste Management Accomplishments During 1999

- Shipped 28 cubic meters of PCB/RCRA/ Rad liquid waste to the TSCA Incinerator
- Treated 6.5 cubic meters of pyrophoric uranium metal chips to meet Envirocare of Utah Waste Acceptance Criteria for future disposal
- Shipped 8 cubic meters of newly generated mixed low level waste to Envirocare of Utah for treatment and disposal
- Shipped 120 cubic meters of low level waste to Envirocare of Utah for disposal
- Issued an Engineering Evaluation/Cost Analysis (EE/CA) for the removal of all scrap metal
- Disposal of 524 cubic meters of reclassified low level waste in the C-746-U landfill
- Awarded the Waste Operations Subcontract to WESKEM LLC
- Characterized 29 waste streams, representing 760 containers of waste under the TCLP FFCA
- Disposed 4,434 cubic meters of industrial waste/construction debris in the C-746-U landfill
- Continued DMSA project field activities and completed corrective actions within 13 DMSAs
- Closed 34 PCB gasket spills and 23 PCB non-gasket spills

- recycling.

The PP/WM Program has the following objectives:

- identifying waste reduction opportunities,
- establishing goals,
- establishing employee awareness of PP/WM principles,
- initiating PP/WM technologies into ongoing projects,
- coordinating recycling efforts,
- identifying PP/WM responsibilities and resource requirements, and
- tracking and reporting results.

Recycling efforts in 1999 included 3.6 metric tons (mt) (7900 pounds) of office paper and 0.06 mt (130 pounds) of aluminum cans. Additional accomplishments of the PP/WM Program included: incorporating micropurging techniques into groundwater sampling resulting in wastewater reductions of approximately 30 cubic meters (m^3); transferring unused chemicals and materials to other programs for re-use; utilizing a centrifuge system to separate slurry generated during drilling activities, resulting in less waste for storage/disposal; utilizing the direct push method in soil sampling to minimize approximately 23 m^3 waste; and reinitiated recycling of printer and fax toner cartridges.

Vortec Vitrification Technology Demonstration

In March 1995, Paducah was selected to be the host site for the demonstration of a vitrification facility developed by the Vortec Corporation. The Vortec process is an innovative use of glass-making technology. The facility has the potential to process low-level, PCB, hazardous, and mixed waste and soils into a glass matrix. The glass matrix is more stable than the waste matrix and is correspondingly better suited for disposal.

During 1996 and 1997, activities proceeded toward siting the vitrification facility at Paducah. DOE and Vortec obtained an air permit from the Commonwealth of Kentucky and worked toward obtaining a RCRA Research, Development, and Demonstration (RD&D) permit. DOE also determined that the proposed action was categorically excluded from NEPA documentation requirements. Vortec began preparing a suitable site to erect the facility and water and power lines were installed to the site. Development of required health and safety, and operational documentation was initiated and characterization of waste streams with potential for treatment by the vitrification facility was performed. The NEPA CX determination was challenged in a lawsuit by a local stakeholder and this resulted in a commitment by DOE to prepare an EA. Work on the EA began in late 1997.

During 1999, a draft EA was distributed a second time for public comment. Communication between DOE and the regulatory agencies was ongoing as permitting issues were being resolved. Vortec completed site preparation and now awaits issuance of a RCRA permit, a revised air permit, and completion of the EA before proceeding.

Depleted Uranium Hexafluoride Cylinder Program

As a result of the uranium enrichment process, DUF_6 is generated. A solid at ambient temperatures, DUF_6 is stored in large metal cylinders. At the end of 1999, the Paducah Site managed an inventory of approximately 37,000 cylinders (most containing DUF_6) stored in outdoor storage facilities commonly referred to as “cylinder yards.” Cylinder yards are constructed of either concrete or compacted gravel. The handling equipment used to stack these cylinders consists of specially designed

machines that grasp and lift the cylinder with hydraulically controlled tines.

The "mission" of the DUF_6 Cylinder Program is to safely store the DOE-owned DUF6 inventory until its ultimate disposition. The DUF_6 Cylinder Program Management Plan was established to meet the program mission. The plan has components (such as DUF_6, cylinders, cylinder yards, cylinder-handling equipment, personnel, and financial resources) and activities (such as operations, management processes, and administration).

The congressional adjustment of DOE's mission from uranium enrichment to uranium inventory management (storage and utilization) has transformed the previous management plan from design, construction, and operation phases to a storage or standby phase. The Program Management Plan for which DOE is responsible has been realigned to containment and use of a finite inventory of DUF_6. The various types of construction and the subsequent deterioration of the yards have led to substandard storage conditions for many of the cylinders. The variety of cylinder designs that have evolved over the years and various paint systems used have resulted in varying corrosion rates. These two main factors led to the need for long-term corrosion monitoring of the cylinders.

Potential risks to people and the environment posed by DUF_6 storage as it is managed are low. The DUF_6 is stored as a crystalline solid at less than atmospheric pressure. When DUF_6 is exposed to the atmosphere, hydrogen fluoride and uranium reaction products form. The uranium by-products form a hard crystalline solid, which acts as a self-sealant within the storage cylinder. The hazard potential of the DUF_6 is primarily chemical toxicity from any released hydrogen fluoride, rather than a radiological hazard.

After visiting the Paducah, Portsmouth, and K-25 [currently identified as East Tennessee Technology Park (ETTP)] sites in 1994 and 1995, the Defense Nuclear Facilities Safety Board (DNFSB) issued Recommendation 95-1 and a supporting technical report. That report addressed the improved safety of cylinders containing DUF_6. Recommendation 95-1 on Depleted Uranium recommended the following:

- Start an early program to renew the protective coating of cylinders containing DUF_6 from the historical production of enriched uranium.
- Explore the possibility of additional measures to protect these cylinders from the damaging effects of exposure to the elements, as well as any additional handling that may occur.
- Institute a study to determine whether a more suitable chemical form should be selected for long-term storage of the depleted uranium.

On June 29, 1995, DOE formally accepted Recommendation 95-1 and emphasized five focus areas for DOE response:

- Removing cylinders from ground contact and keeping cylinders from further ground contact;
- Relocating all cylinders into an adequate inspection configuration (this effort continued in 1999 as new storage yards were constructed or as existing yards were refurbished);
- Repainting cylinders as needed to avoid excessive corrosion (cylinder painting was suspended in 1999);
- Updating handling and inspection procedures and site-specific Safety Analysis Reports; and
- Completing an ongoing study that will include an analysis of alternative chemical forms for the material (on April 15, 1999, DOE issued the *Final*

Programmatic Environmental Impact Statement for Alternative Strategies for the Long-Term Management and Use of Depleted Uranium Hexafluoride).

On October 16, 1995, DOE submitted an Implementation Plan that incorporated complete and near-term actions in accordance with these five focus areas. The Implementation Plan also committed to managing the DUF_6 Cylinder Program using a Systems Engineering Approach. The approach was developed concurrent with field response actions and is enhanced through an open dialogue between DNFSB staff and DOE and Energy Systems personnel. The Implementation Plan specifies the following interim and final deliverables and defines their respective content to establish an operative Systems Engineering process for the continued improvement of DUF_6 management:

- System Requirement Document - identifies the system requirements;
- System Engineering Management Plan - identifies organization, direction, and controls for system integration;
- Engineering Development Plan - identifies development actions, costs, and schedules for technical improvements;
- DUF_6 Cylinder Program Management Plan - identifies costs, schedules, and controls for operating the system and implementing required actions; and
- Approved Safety Analysis Reports - defines the safety envelope.

The system includes several operational functions to maintain containment of the DUF_6. These operational functions are:

- Surveillance and Maintenance;
- Handling and Stacking;
- Contents Transfer; and
- Off-site Transport.

DOE is upgrading the quality of the cylinder yards to help maintain the integrity of the cylinders. Fewer cylinders are stored in the refurbished yards resulting in easier access for inspections to detect corrosion or leaks. To accommodate the resulting space needs, DOE initiated construction of a new 470,000 square feet cylinder yard (C-745-T) which was completed during the spring of 1998. The C-745-L (North) cylinder yard was reconstructed in 1999 and covers 196,000 square feet. The design for refurbishment of more existing storage yards is complete and the reconstruction is planned for FY 2000-2003, pending funding.

In May 1997 the DOE communicated to the DNFSB that two cylinder populations needed to be painted to remain compliant with National Board Inspection Code (NBIC) “in service” pressure vessel standards. At Paducah a population of approximately 3,870 cylinders (former G yard bottom-row cylinders) were identified as requiring to be painted by 2010. Because it was not logical to separate the cylinders on the bottom row from the top row, it was determined that a total of approximately 7,800 cylinders at Paducah would be painted. During fiscal years 1996, 1997, and 1998 a total of 3,368 cylinders were painted. Cylinder painting activities at Paducah were terminated after 1998 in light of DOE’s near term plans to begin conversion of the depleted UF6 in 2005. If conversion begins in 2005 the remaining worst case cylinders can be converted by 2010. If conversion does not become operational in 2005, alternative mitigating actions, such as restarting cylinder painting operations will need to be implemented.

In December 1998 toxicity test results at KPDES Outfall 017 exceeded the KPDES limit for toxicity (see discussion in Section 2). Subsequent tests confirmed the toxicity exceedance and a Toxicity Reduction Evaluation Plan was established. Zinc from cylinder

painting operations was suspected as the primary cause of the toxicity. Additional sampling and monitoring at Outfall 017 is scheduled to continue through March 2001. Any future cylinder painting operations at Paducah will consider the use of non-zinc based paints.

Public Awareness Program

A comprehensive community relations and public participation program on DOE activities exists at the Paducah site. The purpose of the program is to conduct a proactive public involvement program, with outreach components, to foster a spirit of openness and credibility among local citizens and various segments of the public. The program is also geared to provide the public with opportunities to become involved in decisions affecting environmental issues at the site.

Community/Educational Outreach

DOE and Bechtel Jacobs Company LLC Public Affairs sponsored several educational and community outreach activities during 1999, such as Environmental Day which was cosponsored with the Paducah Chamber of Commerce and the 1999 Leadership Paducah class. A broad-scope public meeting was conducted in July. In August and September, DOE Headquarters also hosted public meetings in the Paducah area.

Earth Day

DOE, Bechtel Jacobs, and the Kentucky Division of Fish and Wildlife Resources(KDFWR) jointly sponsored, planned and implemented the 1999 Earth Day activities (Figure 3.2). The two-day event involved more than 800 sixth-grade students from area school systems. A wide variety of environmental educational programs were provided using both the WKWMA and DOE property. Many of the activities were hands-on, with students making decisions and taking actions regarding hypothetical environmental problems.

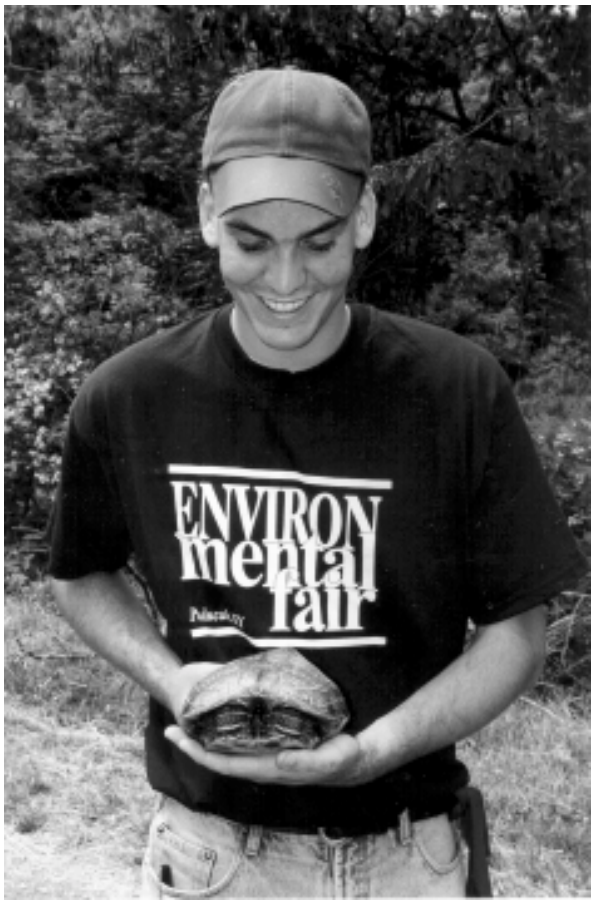

Figure 3.2 Earth Day 1999.

Site Specific Advisory Board

The PGDP Site Specific Advisory Board(SSAB), a citizens advisory board, chartered by the DOE under the Federal Advisory Committee Act, completed its third full year of operation in September 1999. The SSAB received its charter in August 1996, and consists of individuals with diverse backgrounds and interests. The SSAB meets monthly to focus on early citizen participation in environmental cleanup priorities and related issues at the DOE facility. The SSAB participates only in activities that are governed by DOE and regulated by KDEP and EPA Region IV. During 1999, the SSAB held 11 regular meetings and one special-topic meeting, all open to the public and publicly noticed. The SSAB advised and made

recommendations to DOE on several projects and issues, and commented on a number of documents released during the period. In 1999, the SSAB had up to 18 voting members, five *exofficio* members, and a Deputy Designated Federal Official.

Environmental Information Center

The public has access to the Administrative Record and programmatic documents at the DOE Environmental Information Center in the West Kentucky Technology Park, 175 Freedom Boulevard, Kevil, Kentucky. In addition, documents for public comment are placed in the McCracken County Public Library (formerly the Paducah Public Library), 555 Washington Street, Paducah, Kentucky. The library is open Monday through Thursday from 9 a.m. to 9 p.m., Friday and Saturday from 9 a.m. to 6 p.m., and Sunday from 1 to 6 p.m.

Other Activities

In accordance with Issue #2, PGDP-INV-99-02, Action 2A-1 of the Corrective Action Plan in Response to the DOE *Phase I Independent Investigation of the Paducah Gaseous Diffusion Plant* (BJC/OR-453/R1), temporary radiological postings were installed at several locations during the week of October 18, 1999. (These have since been replaced with permanent postings.) The postings warn of various radiological contamination areas both inside and outside the PGDP security fence. Postings were placed only in those areas on DOE property where data exist which indicate contamination at levels above the 10 CFR 835 requirements. Posting locations outside the PGDP security fence include: the North-South Diversion Ditch from the plant security fence to KY 358 (Ogden Landing Road); KPDES Outfall Ditch 011; Little Bayou Creek and institutional controls near KY 358; Little Bayou Creek and institutional controls near McCaw Road; KPDES Outfall 015; and several WAG 17 rubble piles (BJC 2000a).

4 Radiological Effluent Monitoring

Abstract

Radiological liquid effluent monitoring was performed at the four outfalls under the jurisdiction of DOE at the Paducah Site during 1999. Three of the four outfalls retained by DOE contain only rainfall runoff. A fourth outfall is a continuous flow outfall. The outfalls were monitored for radionuclides historically present at the site. Concentrations of the radionuclides measured (uranium and ^{99}Tc) for DOE outfalls were within acceptable limits set by DOE and by state and federal standards. The only DOE-operated point source for radionuclides in airborne effluents during 1999 was the Northwest Plume Groundwater System where contaminated groundwater was pumped from the ground and treated to remove TCE and ^{99}Tc.

Introduction

Effluents are monitored for radionuclides known to be emitted or to have been present at the site. Dose calculations are provided in Section 6. In 1999, sampling and analytical activities were the responsibility of Bechtel Jacobs Company LLC. Monitoring of radioactivity in liquid and airborne effluents is described fully in the *Paducah Site Environmental Monitoring Plan* (BJC 1998).

Airborne Effluents

In 1993, DOE leased the enrichment operations facilities at the PGDP to USEC. At this time, USEC assumed responsibility for all existing radionuclide point-source discharges. A small number of fugitive radionuclide emission sources, such as roads and scrap metal piles, were retained by DOE. A potential fugitive or diffuse source of radionuclides also results from the decontamination of machinery and equipment used in remediation activities such as well drilling. The equipment is washed with high-powered sprayers to remove any contaminants picked up from contaminated soil and groundwater. The concentrations of radionuclides on the equipment are so small that under most circumstances contamination cannot be distinguished from background.

On August 28, 1995, DOE began operation of its only current radionuclide point source, the Northwest Plume Groundwater System. The facility is located just outside of the northwest corner of the PGDP security area. The facility consists of an air stripper to remove volatile organics from water and an ion exchange unit for the removal of ^{99}Tc. The air stripper is located upstream of the ion exchange unit. The ^{99}Tc concentration in the influent and effluent of the

air stripper and the quantity of the water passing through the air stripper were used to calculate the total quantity of ^{99}Tc emitted from the facility in 1999.

Applicable Regulations

DOE Order 5400.1, *General Environmental Protection Program*, requires that effluent monitoring be conducted at all DOE sites. DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, sets annual dose standards for members of the public of 10 millirems (mrem) per year from airborne releases and 100 mrem/year through all exposure pathways resulting from routine DOE operations. Radiological airborne releases are also regulated by EPA under *Title 40* of the *U.S. Code of Federal Regulations, Part 61* (40 CFR 61), Subpart H, which covers radionuclide emissions, other than radon, from DOE facilities. This regulation was amended in 1989 to include specific sampling requirements for each emission point with the potential to emit radionuclides resulting in an effective dose equivalent of 0.1 mrem to the most affected off-site resident. When determining potential emissions, it is assumed that air pollution abatement devices do not exist, but that the facility is otherwise operating normally.

Per 40 CFR 61 Subpart H, DOE must report radionuclide emissions by June 30th of each year to EPA via a National Emission Standards for Hazardous Air Pollutants (NESHAP) Report. The EPA-approved methodologies for sampling and calculations must be used to address effluents.

Under CERCLA, a ROD was signed July 22, 1993, for the Northwest Plume Groundwater System. Although administrative requirements of environmental regulations need not be met for projects conducted under CERCLA, DOE has continued to supply all permit-related documentation to regulators. The Operations and Maintenance Plan approved by the EPA in March 1995 (and since revised), describes sampling and methodologies to be used at the Northwest Plume Groundwater System. The sampling protocol has been used to develop a mass balance differential to quantify the radionuclide stack effluent from the facility. The analysis of the water before and after the air stripper stack provides a much more accurate measure of airborne discharges than actual stack measurements due to the low, practically immeasurable radionuclide airborne effluents associated with the facility.

Airborne Effluent Results

In 1999, releases to the atmosphere from the Northwest Plume Groundwater System were calculated to be 1.38×10^{-2} (0.0138) curies. Dose to the public from airborne radionuclides is discussed in Section 6.

Liquid Effluents

In addition to nonradiological parameters on the KPDES permit, specific radionuclide analyses and indicator gross activity analyses are conducted on liquid effluent samples. Grab samples and composite samples at various frequencies are used to measure discharges (Figure 4.1). DOE was responsible for a total of four outfalls in 1999. Under KPDES permit number KY0004049, Outfall 001 was a continuous flow outfall that received discharges from USEC's Phosphate Reduction Facility, USEC's once-through cooling water, DOE's Northwest Plume Groundwater System, and DOE's Northeast Plume Containment System. In addition, surface water runoff from the northeast side of the plant also discharged into Outfall 001. Outfall 015 received surface water runoff from the east central sections of the plant. Outfall 017 received surface water runoff from the southeast section of the plant (primarily the cylinder yards). Outfall 019 received surface water runoff from C-746-U (DOE's operational landfill).

Figure Not Approved For Web Release

Figure 4.1 KPDES outfall locations at the Paducah Site. Outfalls 001, 015, 017, and 019 are the responsibility of DOE.

Applicable Regulations

The EPA safe drinking water limits for groundwater do not apply to Paducah Site surface water sampling as effluent ditches and Bayou and Little Bayou Creeks are not drinking water sources for public or private use. However, DOE Orders 5400.1 and 5400.5 define effluent monitoring requirements to provide confidence that radiation exposure limits are not exceeded. Although no specific effluent limits for radiological parameters are included on the KPDES permit, DOE Order 5400.5 sets guidelines for allowable concentrations of radionuclides in various effluents and requires radiological monitoring to protect public health. This protection is achieved at the Paducah Site by meeting the DOE Order 5400.5 derived concentration guidelines (DCGs), which are the concentrations of given radionuclides that would result in an effective dose equivalent of 100 mrem/year. The DCGs are based on the assumption that a member of the public has continuous, direct access to the liquid effluents which is a conservative exposure scenario not likely to exist.

Liquid Effluent Monitoring Program

Sample Collection Systems

For monitoring purposes, the Paducah Site uses estimates of DCG levels and outfall flow characteristics (rainfall dependent) to determine sampling frequencies. Although the Paducah Site monitors for other radionuclides, uranium and ^{99}Tc are the primary radionuclides of concern. Neither continuous monitoring nor continuous sampling are required by DOE Order 5400.5. Analyses are performed for dissolved alpha, suspended alpha, dissolved beta, and suspended beta activity. Data is provided in Appendix C.

Surface runoff from the closed C-746-S residential landfill and the C-746-T inert landfill is monitored quarterly. Due to their close proximity, they are monitored as one landfill (Figure 4.2). Also, surface runoff is monitored from the C-746-U operating contained landfill. Surface runoff from these landfills is monitored for uranium, gross alpha, and gross beta. Grab samples are taken from the landfill runoff, the receiving ditch upstream of the runoff discharge point, and the receiving ditch downstream of the runoff discharge point. Sampling is performed to comply with KDWM permit requirements for landfill operations. The landfills will continue to be monitored for at least 30 years from the date of closure. Data is presented in Appendix C.

Liquid Effluent Monitoring Results

Tables 4.1 and 4.2 give the yearly minimum, maximum, and average concentrations of uranium and ^{99}Tc, respectively, at each outfall monitoring location. Each radionuclide is compared with the corresponding DCG and is presented as a percentage of that standard. The average concentrations at all outfalls were small percentages of the corresponding DCGs. Outfall 015 receives runoff from the uranium burial grounds with small quantities of surface contamination from uranium compounds. That runoff is responsible for the elevated ^{99}Tc and uranium concentrations associated with Outfall 015. The average concentration of uranium being discharged to Outfall 015 was 14.7% of

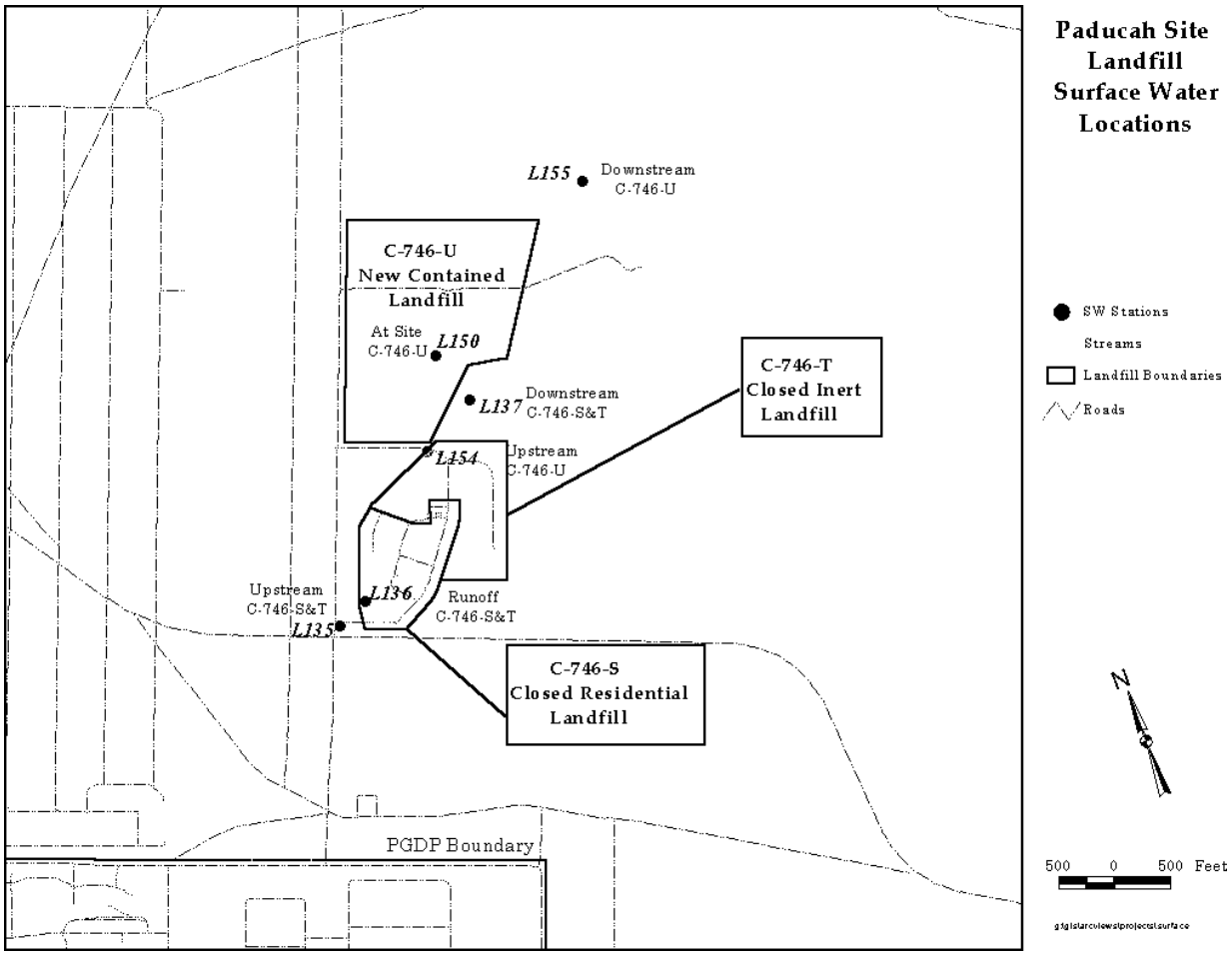

Figure 4.2 Landfill surface water monitoring locations.

Table 4.1 Total Uranium Concentration in DOE Outfalls for 1999

Outfall	No. of Samples	Concentration (mg/L) Min.	Max.	Avg.	(pCi/L)[a] Avg.	$\%^{235}U$	% of DCG[b]
001	4	0.001	0.073	0.029	15.1	0.47	2.5
015	4	0.085	0.260	0.185	88.1	0.40	14.7
017	4	0.001	0.007	0.004	2.3	0.55[c]	0.3
019	2	0.001	0.001	0.001	0.7	0.76[d]	0.1

[a] 1 pCi/L = 0.037 Bq/L

[b] DCG for uranium is 600 pCi/L

[c] Insufficient uranium quantities to analyze for assay, assay based on past data

[d] Insufficient uranium quantities to analyze for assay, natural uranium used as assay

Table 4.2 ^{99}Tc Concentration in DOE Outfalls for 1999

Outfall	No. of Samples	Concentration (pCi/L)[a] Min.	Max.	Avg.	% of DCG[b]
001	4	1	24	14	0.014
015	3	27	90	53	0.053
017	4	1	28	12	0.012
019	1	13	13	13	.013

[a] 1 pCi/L = 0.037 Bq/L

[b] DCG for ^{99}Tc is 100,000 pCi/L

the DCG. The average concentration of uranium being discharged to Outfalls 001, 017, and 019 was less than 3% of the DCG.

Technetium averages for 1999 were well below 1% of the 100,000 pCi/L DCG. Data for 1999 do not show a significant change in relation to DCG levels for either radionuclide compared to data for the past five years. Figures 4.3 and 4.4 show a five-year summary of average concentrations of uranium and ^{99}Tc concentrations. Additional data is in Appendix C.

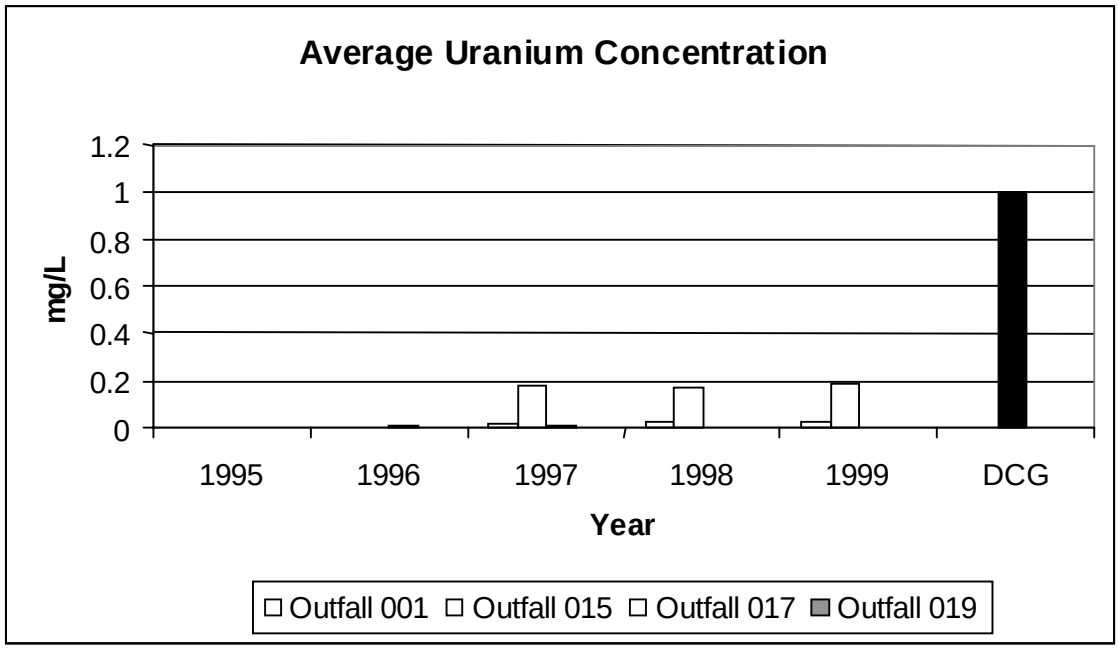

Figure 4.3 Uranium concentrations discharged to surface water, 1995 - 1999.
Note: Outfalls 001 and 015 were leased to USEC from 1995 to 1996; therefore, no data is provided.
(DCG for Uranium is 1 mg/L at 0.7% assay.)

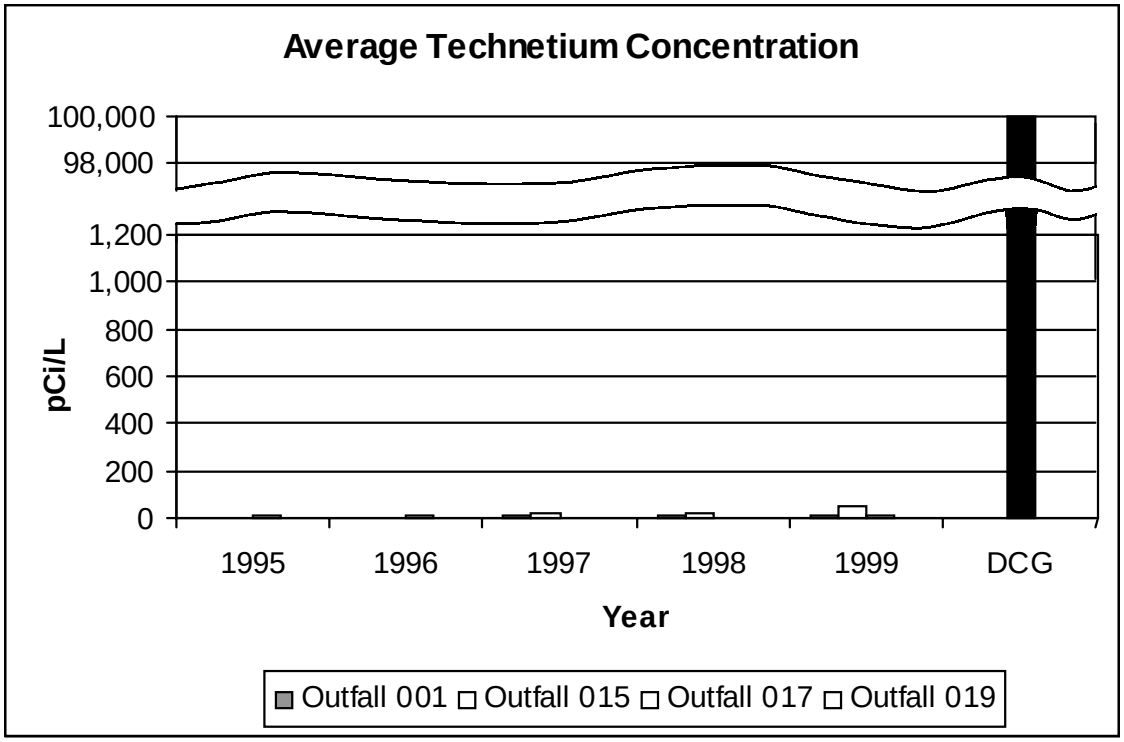

Figure 4.4 Technetium concentrations discharged to surface water, 1995 - 1999.
Note: Outfalls 001 and 015 were leased to USEC from 1995 to 1996; therefore, no data is provided.

5 Radiological Environmental Surveillance

Abstract

The radiological environmental surveillance program assesses the effects of DOE activities on the surrounding population and environment. Surveillance includes analyses of surface water, groundwater (Section 9), sediment, terrestrial wildlife, and direct radiation. Surveillance results indicate that radionuclide concentrations in sampled media were within applicable standards in 1999.

Introduction

The radiological environmental surveillance program at the Paducah Site is based on DOE Orders 5400.1, *General Environmental Protection Program*, and 5400.5, *Radiation Protection of the Public and the Environment*, which require that an environmental surveillance program be established at all DOE sites to monitor the effects, if any, of DOE activities on the surrounding population and environment. Surveillance includes analyses of surface water, groundwater (Section 9), sediment, terrestrial wildlife, and direct radiation.

Ambient Air

Per the 1993 DOE/USEC transition, USEC is responsible for the existing radionuclide airborne point-source discharges at PGDP, with the exception of DOE's Northwest Plume Groundwater System. DOE has fugitive emission sources including piles of contaminated scrap metal, roads, and concrete rubble piles. DOE utilized ambient air monitoring data to verify insignificant levels of radionuclides in off-site ambient air. Ambient air data is collected at eight sites surrounding the plant in order to measure radionuclides emitted from Paducah Site sources including fugitive emissions. The Radiation/Environmental Monitoring Section of the Radiation Health and Toxic Agents Branch of the Department for Public Health of the Kentucky Cabinet for Health Services conducted the ambient air monitoring during 1999 (KCHS). Based on observations for 1999, airborne radionuclides emitted from the Paducah Site, including the PGDP, were not detected by the ambient air monitors.

Meteorological Monitoring

DOE Order 5400.1 requires that DOE facilities collect representative meteorological data in support of environmental monitoring

activities. This information is essential to characterize atmospheric transport and diffusion conditions in the vicinity of the Paducah Site.

On-site meteorological data are used as input to calculate radiation dose to the public (see Section 6). Additional meteorological data from Barkley Regional Airport are used by some groups. For example, the Environmental Restoration Program uses this data to correlate precipitation with groundwater flow.

Computer-aided atmospheric dispersion modeling uses emission and meteorological data to determine the impacts of plant operations. Modeling is used to simulate the transport of air contaminants and to predict the effects of abnormal airborne emissions from a given source. In addition, a multitude of emergency scenarios can be developed to estimate the effects of unplanned releases on employees and population centers downwind of the source.

Surface Water

All Paducah Site surface water runoff is released either to the west to Bayou Creek or to the east to Little Bayou Creek via plant outfalls. Bayou and Little Bayou creeks merge north of the site and discharge into the Ohio River. The net impact of the Paducah Site on surface waters can be evaluated by comparing data from samples collected upstream of the site with data from samples collected downstream of the site or from reference waterways. Bayou and Little Bayou Creeks are considered to be waters of the Commonwealth of Kentucky and designated for all uses by the Commonwealth. However, because these creeks are not used as drinking water supplies, EPA safe drinking water standards do not apply. Radioactive effluents are controlled via DOE Order 5400.5.

Bimonthly radiological sampling is conducted at upstream Bayou Creek (L 1), downstream Bayou Creek (L 5), downstream Little Bayou Creek (L 10 and L 11), upstream Ohio River (L 29), downstream Ohio River (L 30), downstream in the Ohio River at the confluence with the Mississippi River (L 306), and reference stream Massac Creek (L 64). No sample point exists for upstream Little Bayou Creek as the watershed is insufficient to develop adequate flow to monitor. Nearly all water in Little Bayou Creek is comprised of discharges from plant outfalls. Therefore, background water quality for Little Bayou Creek is based on L 1 (upstream Bayou Creek). L 29 and L 64 are reference waterways also used for comparisons with data for Little Bayou Creek surveillances. Figure 5.1 shows all surface water sampling locations, including those used only for nonradiological sampling (Section 8). Table 5.1 shows the radiological analytical parameters.

Surface Water Surveillance Results

Table 5.2 reflects the average concentrations of radionuclides present upstream and downstream of plant effluents in Bayou Creek

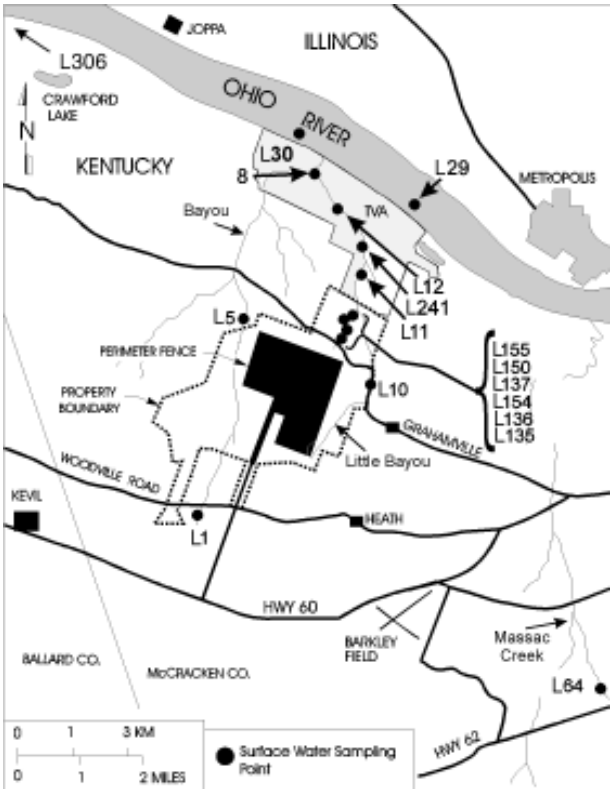

Figure 5.1 Surface water monitoring locations.

Table 5.1 Routine Radiological Sampling Parameters for Surface Water Surveillance for 1999

Station	Parameter	Sample Type
L 1, L 5, L 10, L 11, L 29, L 30, L 64, L 306	Dissolved alpha and beta, suspended alpha and beta, ^{237}Np, ^{239}Pu, ^{99}Tc, total U, % ^{235}U, ^{235}U, ^{238}U, ^{230}Th, gross gamma	Grab

and downstream of plant effluents in Little Bayou Creek. Comparisons of downstream data with upstream data and reference waterways can be made to determine the influence of plant effluents on these waterways.

The downstream Bayou Creek location shows an increase in uranium and no change for ^{99}Tc when compared to the upstream Bayou Creek location. The downstream Little Bayou Creek locations both show an increase in uranium and one shows an increase in ^{99}Tc when compared to the upstream Bayou Creek location. ^{239}Pu and ^{230}Th were found to be highest in the upstream Ohio River location. Concentrations of radionuclides found are at levels far below DCGs and do not pose a health risk.

L 8, L 12, L 223, and L 241 are nonroutine sample locations. L 135, L 136, L 137, L 150, L 154, and L 155 are surface water runoff samples from the C-746-S, T, and U landfills. Data for these locations is provided in Appendix C.

Table 5.2 Selected Routine Radiological Surface Water Surveillance Results (Average Concentrations)

Parameter	L 1 Upstream Bayou	L 5 Down-stream Bayou	L 10 Down-stream Little Bayou	L 11 Down-stream Little Bayou	L 29 Upstream Ohio River	L 30 Down-stream Ohio River	L 64 Massac Creek	L 306 Confluence of Ohio and Mississippi
Total Uranium (mg/L)	ND	0.004	0.010	0.005	ND	ND	ND	ND
^{99}Tc (pCi/L)	ND	ND	ND	10.0	1.92	13.0	ND	ND
^{237}Np (pCi/L)	0.213	ND	0.34	ND	ND	0.378	0.277	ND
^{239}Pu (pCi/L)	ND	ND	ND	ND	0.047	ND	ND	ND
^{230}Th (pCi/L)	0.034	ND	ND	ND	0.095	ND	ND	ND
^{235}U (pCi/L)	--	--	0.502	--	--	--	--	--
^{238}U (pCi/L)	--	--	6.69	--	--	--	--	--

ND = not detected
-- = not measured

Sediment

Sediment is an important constituent of the aquatic environment. If a pollutant is a suspended solid or is attached to suspended sediment, it can settle to the bottom (thus creating the need for sediment sampling), be taken up by certain organisms, or become attached to plant surfaces. Pollutants in solution can adsorb on suspended organic and inorganic solids or be assimilated by plants and animals. Suspended solids, dead biota, and excreta settle to the bottom and become part of the organic substrata that support the bottom-dwelling community of organisms.

Sediments play a significant role in aquatic ecology by serving as a repository for radioactive or chemical substances that pass via bottom-feeding biota to the higher trophic levels. Figure 5.2 shows possible exposure routes of trace metals (including uranium) in an aquatic ecosystem.

Sediment Surveillance Program

As a result of DOE's retaining responsibility for historic environmental issues and problems, ditch sediments are sampled annually through a radiological environmental surveillance program.

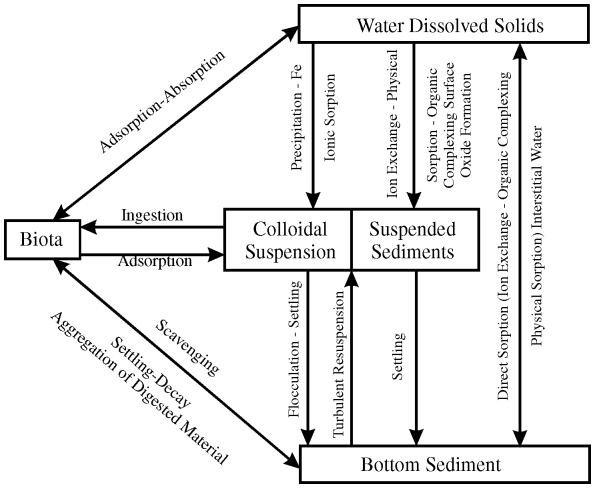

Figure 5.2 Routes of trace metals in an aquatic ecosystem (Jinks and Eisenbud 1972).

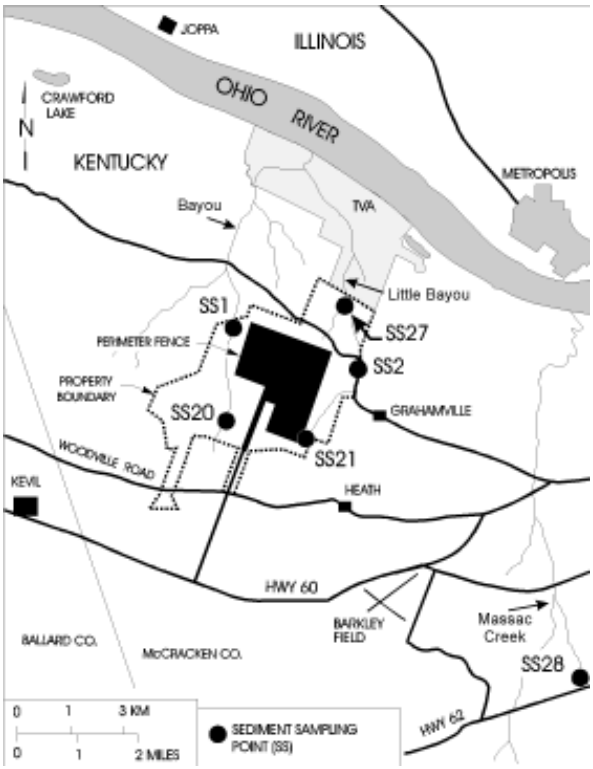

Figure 5.3 Routine sediment sampling locations.

Sediment samples were taken from six locations (Figure 5.3). Table 5.3 shows the radiological analytical parameters.

Sediment Surveillance Results

Table 5.4 shows the radionuclide sediment sampling results for 1999. Locations SS 1, SS 2, and SS 27 are downstream of plant effluents. Locations SS 20, SS 21, and SS 28 are considered reference, or background sites, and can be used to compare with downstream data. SS 20 and SS 21 are on different creeks upstream of the plant

Table 5.3 Radiological Sampling Parameters for Sediment Surveillance at the Paducah Site for 1999

Station	Parameter
SS 1, SS 2, SS 20, SS 21, SS 27, SS28	^{137}Cs, ^{40}K, ^{237}Np, ^{239}Pu, ^{99}Tc, ^{230}Th, total U, ^{234}U, ^{235}U, ^{238}U, ^{60}Co, ^{241}Am, alpha activity, beta activity

Table 5.4 Routine Radionuclide Sediment Sampling Results at the Paducah Site for 1999

	Parameter													
	pCi/g													
	^{99}Tc	^{237}Np	^{239}Pu	^{230}Th	^{137}Cs	^{40}K	^{60}Co	^{241}Am	alpha activity	beta activity	^{234}U	^{238}U	^{235}U	%^{235}
Background Locations														
Bayou Creek														
SS20	ND	ND	ND	ND	ND	0.961	ND	ND	2.13	1.02	0.23	0.257	0.012	0.69
Little Bayou Creek														
SS21	ND	ND	ND	ND	ND	4.16	ND	ND	3.78	2.82	0.17	0.247	0.009	0.57
Massac Creek														
SS28	ND	ND	ND	ND	ND	0.367	ND	ND	0.83	0.89	0.06	0.07	0.003	0.69
Downstream Locations														
Bayou Creek														
SS1	ND[b]	ND[a]	ND[a]	ND[a]	0.030[c]	1.612[a]	ND[a]	ND[a]	4.2[a]	3.22[a]	0.54[a]	0.854[a]	0.030[a]	0.54
Little Bayou Creek														
SS2	17.85[c]	ND	ND	0.247	ND	1.5	ND	ND	6.51	9.58	0.65	4.66	0.069	0.23
SS27	4.005[a]	ND	0.090	1.08	0.044	ND	ND	ND	10.05	7.29	1.59	3.34	0.096	0.44

[a] average of two samples reported
[b] average of four samples reported
[c] average of two samples reported, one detected result and one at detection level

discharges, whereas SS 28 is located in a similar type stream providing a regional reference site.

The Bayou and Little Bayou Creek downstream concentrations are higher than the background upstream concentrations for all uranium radionuclides. The uranium increase is attributed to plant operations. This is verified by the assay values (% ^{235}U present) that are lower than would be seen for naturally occurring uranium (about 0.7% assay). These results concur with past studies in which uranium was detected. As shown in Table 5.5, total uranium concentrations in sediment in 1999 were not analyzed to a low enough level to be compared with past years.

The Little Bayou Creek downstream concentrations are higher than the background upstream concentration for ^{99}Tc. Table 5.6 shows that ^{99}Tc concentration in sediment at SS 2 increased significantly in 1999, similar to the increase noted at SS 1 in 1998. Historical data collected in the past five years indicates that these increases at SS 2 and SS 1 may be anomalies because the value for ^{99}Tc is significantly higher than for the other years. Continued surveillance will prove or disprove this assumption. Other radionuclides, although present, are not significantly above background values.

Terrestrial Wildlife

Annual Deer Harvest

In 1999, a total of eight deer were harvested in the WKWMA as part of DOE's ongoing effort to monitor the effects of the Paducah Site on the ecology of the surrounding area. Two deer obtained as background samples from the Ballard Wildlife Management Area (BWMA) were used for reference. Liver, muscle, and bone samples were analyzed for several radionuclides [^{137}Cs, ^{237}Np, ^{239}Pu, ^{99}Tc, ^{230}Th, ^{234}U, ^{235}U, ^{238}U, and ^{90}Sr (bone samples only)]. In addition, thyroid samples were analyzed for ^{99}Tc. Because the liver and muscle tissue are considered consumable by hunters, these tissues can be evaluated for radiological risks (dose) if analyses reveal detectable levels above background, or reference, deer. Bone and thyroid samples are used only as indicators of contamination. Table 5.7 lists deer with detectable levels of radionuclides.

Table 5.5 Five-Year Uranium Concentrations in Sediment

	Total Uranium (g/g)				
	1995	**1996**	**1997**	**1998**	**1999**
Upstream/Reference Locations					
		Big Bayou Creek			
SS 20	0.9	5.1	0.83	0.83	ND
		Little Bayou Creek			
SS 21	2.2	2.6	2.24	2.32	ND
		Massac Creek			
SS 28	0.51	1.8	0.31	0.33	ND
Downstream Locations					
		Big Bayou Creek			
SS 1	2.97	3.5	2.59	60.1	ND
		Little Bayou Creek			
SS 2	12.5	43.5	21.3	12.4	ND
SS 27	8.6	10.0	10.8	2.18	ND

Table 5.6 Five-Year ^{99}Tc Concentrations in Sediment

	^{99}Tc (pCi/kg)				
	1995	**1996**	**1997**	**1998**	**1999**
Reference Locations					
Big Bayou Creek					
SS 20	516	100	334	810	ND
Little Bayou Creek					
SS 21	534	114	220	450	ND
Massac Creek					
SS 28	624	174	332	210	ND
Downstream Locations					
Big Bayou Creek					
SS 1	795	597	742	90730	ND
Little Bayou Creek					
SS 2	495	508	621	590	17850
SS 27	560	4935	6042	3600	4005

In deer bone, ^{237}Np was found slightly above the detection level in one background deer. Strontium-90 was found above detection levels in two WKWMA deer. Thorium-230 was found above detection levels in three WKWMA deer and one background deer. Uranium-234 was found above detection levels in four WKWMA deer. Uranium-235 was found above detection levels in one background deer. Uranium-238 was found above detection levels in two WKWMA deer. Although detectable levels of radionuclides were found none of the concentrations were significantly above background concentrations. In addition, the bone of deer are not consumed by humans and are not normally considered a source of human dose.

In the deer liver, ^{237}Np was found above the detection level in one WKWMA deer. Thorium-230 was found above detection levels in two WKWMA deer. Although detectable, no significant concentrations of radionuclides were found.

In the deer muscle, which is normally considered to be edible to humans, ^{230}Th was found above detectable levels in two WKWMA deer. Uranium-234 was found above detectable levels in two WKWMA deer. Uranium-235 was found above detectable levels in two WKWMA deer. Uranium-238 was found above detectable levels in one WKWMA deer. The concentrations of radionuclides detected were not significantly higher than background deer.

Additional data is provided in Appendix C.

Non-Routine Rabbit Sampling

At the request of KDFWR, rabbit sampling was conducted in 1999. Muscle tissue from eight rabbits collected at WKWMA was sampled for several radionuclides. One radionuclide, ^{234}U, was detected in one rabbit. The concentration of ^{234}U in that rabbit was not considered significant.

Table 5.7 Summary of Radionuclides Detected in Deer Samples in 1999

Deer #	Sample Type	Radionuclide	Results (pCi/g)
		WKWMA Deer	
1	Bone	Thorium - 230	0.29
1	Bone	Uranium - 234	0.047
1	Liver	Neptunium - 237	0.009
1 Dup	Muscle	Thorium - 230	0.005
1 Dup	Muscle	Uranium - 234	0.012
3	Bone	Thorium - 230	0.015
2	Bone	Uranium - 238	0.008
3	Liver	Thorium - 230	0.012
3	Muscle	Uranium - 235	0.006
4	Muscle	Uranium - 238	0.006
5	Bone	Uranium - 234	0.022
6	Bone	Uranium - 234	0.029
6	Bone	Uranium - 238	0.012
7	Bone	Strontium -90	3.4
7	Liver	Thorium - 230	0.017
7	Muscle	Thorium - 230	0.005
7	Muscle	Uranium - 234	0.02
8	Bone	Strontium -90	3.2
8	Bone	Thorium - 230	0.03
8	Bone	Uranium - 234	0.029
		Background Deer	
9	Bone	Neptunium - 237	0.013
10	Bone	Thorium - 230	0.03
	Bone	Uranium - 235	0.018

Additional data is provided in Appendix C.

Direct Radiation

A primary pathway of concern for DOE's operations at the Paducah Site is direct external radiation exposure. External radiation exposure is defined as exposure attributed to radioactive sources outside the body (e.g., cosmic gamma radiation). Sources of external radiation exposure from the Paducah Site include cylinder storage yards, the cascade system, and small sources such as instrument check locations. Cylinder storage yards have the largest potential for a dose to the public because of their proximity to the PGDP security fence.

The *Paducah Site Environmental Monitoring Plan* (BJC 1998) establishes DOE's program for monitoring external gamma radiation at areas accessible to members of the public. The external radiation exposure monitoring program has the following three objectives:

- to establish the potential radiation dose received by a member of the public from direct exposure to DOE operations at the boundary of the DOE perimeter fence,
- to establish the potential dose a member of the public may receive visiting or passing through accessible portions of the DOE reservation, and
- to calculate the radiation dose equivalent to the maximally exposed individual member of the public.

In 1999, monitoring consisted of quarterly placement, collection, and analysis of environmental thermoluminescent dosimeters (TLDs). Monitoring results indicate that four locations were consistently above background levels (BJC 2000b). These locations were all at or near the PGDP security fence in the vicinity of UF_6 cylinder storage yards (Figures 5.4 and 5.5).

Annual dose rates for the background locations and the three locations above background were calculated. The mean annual background exposure was determined to be 99 mrem. For each location, the mean background exposure was subtracted from the annualized total exposure to obtain a net annual exposure. The net annual exposure represents the total exposure at that location, for the entire calendar year 1999, attributed to the Paducah Site (Table 5.8). All exposure measured at these locations is assumed to result from DOE operations. Dose from direct radiation exposure is discussed in Section 6.

Additional data is provided in Appendix C.

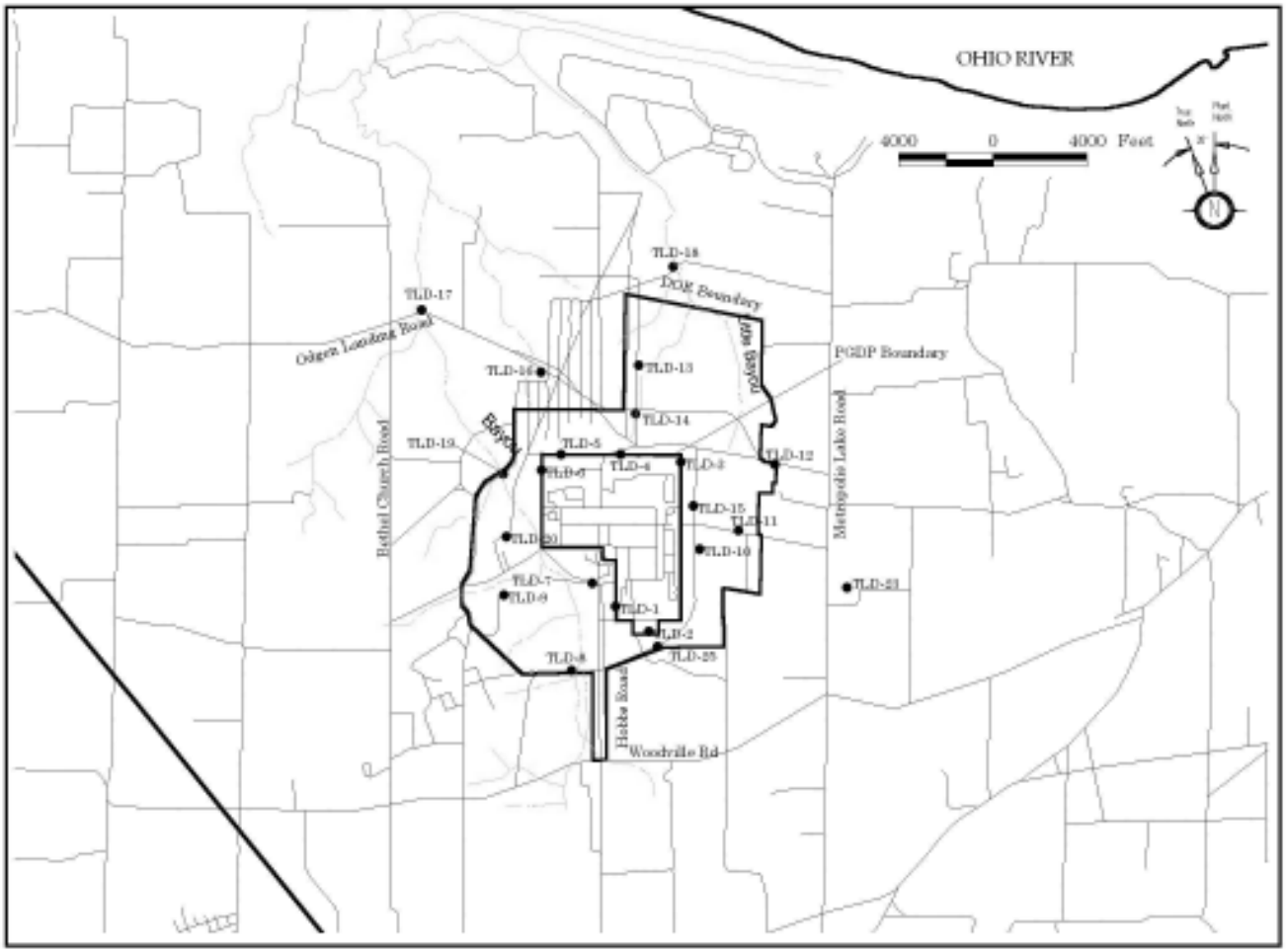

Figure 5.4 TLD locations in the vicinity of PGDP.

Table 5.8 Net Annual Exposure from Direct Radiation Attributed to the Paducah Site for 1999 (mrem)

Location	TLD-1	TLD-2	TLD-3	TLD-25
total annual exposure	424	732	757	111
background	99	99	99	99
net annual exposure	325	633	658	12

Figure 5.5 Uranium hexafluoride cylinder storage yard.

6 Dose

Abstract

For 1999, exposure pathways potentially contributing to dose were determined to include ingestion of surface water, ingestion of sediments, ingestion of deer meat, direct radiation, and atmospheric releases. The highest estimated dose a maximally exposed individual might have received from all combined DOE exposure pathways (worst-case scenario) was 0.69 mrem. This dose is a small fraction of the applicable federal dose standard of 100 mrem/year.

Introduction

This section presents the calculated doses to individuals and the surrounding population from atmospheric and liquid releases from the Paducah Site, as well as direct radiation (Sections 4 and 5). In addition, potential doses from special case exposure scenarios, such as deer meat consumption, were calculated based upon deer sample analyses.

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, limits the dose to members of the public to less than 100 mrem/year total effective dose equivalent from all pathways resulting from operation of a DOE facility. Information on the demography and land use of the area surrounding the plant and identification of on-site sources have indicated certain radionuclides and exposure pathways. Figures 6.1 and 6.2 give a comprehensive view of the possible pathways between radioactive

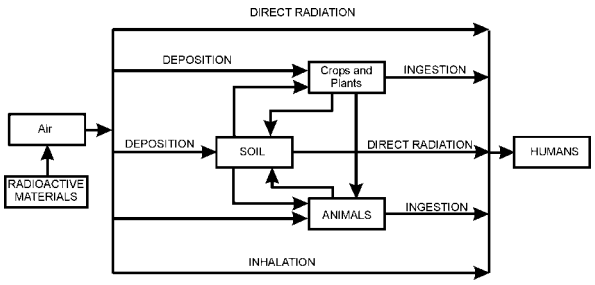

Figure 6.1 Potential pathways between radioactive material released to the atmosphere and individuals.

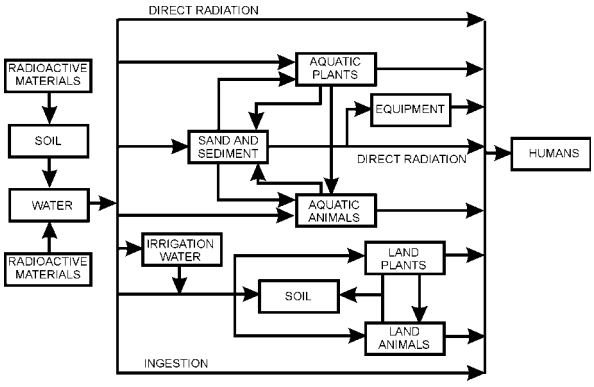

Figure 6.2 Potential pathways between radioactive material released to surface water and individuals.

materials released to the environment and human beings. In practice, only a few pathways constitute the major sources of exposure in any given situation.

For the Phase I Remedial Action Site Investigation, CH2M Hill conducted a preliminary assessment of risk to the health of the public from contaminants at the Paducah Site (CH2M Hill 1990). This study identified four primary pathways that each could contribute greater than 1% to the total off-site dose: groundwater ingestion, sediment ingestion, wildlife ingestion, and exposure to direct radiation. Since that preliminary assessment, groundwater wells that supplied drinking water in the downgradient direction from the PGDP have been sealed to prevent use, resulting in a loss of that pathway. In addition, the Northwest Plume Groundwater System began operation in 1995 resulting in an airborne pathway now included in the dose calculations. Furthermore, in 1999 a drinking water pathway was added for consumption of surface water at the nearest public drinking water source (Ohio River at Cairo, Illinois).

To fully assess the potential dose to the public, a hypothetical group of extreme characteristics is used to postulate an upper limit to the dose of any real group. This is referred to as the worst-case scenario. Actual dose received is likely to be considerably less than the dose calculated for the worst-case scenario.

Terminology and Internal Dose Factors

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; 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.

A number of specialized units have been defined for characterizing exposures to radiation as defined in Appendix A. Because the damage associated with such exposures results primarily from the deposition of radiant energy in tissue, the units are defined in terms of the amount of incident radiant energy absorbed by tissue and of the biological consequences of that absorbed energy. These units include the following:

- *Committed effective dose equivalent (CEDE)*—the total internal dose (measured in mrem) received over a 50-year period resulting from the intake of radionuclides in a 1-year period. The CEDE is the product of the annual intake (pCi) and the dose conversion factor for each radionuclide (rmem/pCi).

- *Effective dose equivalent*—includes the CEDE from internal deposition of radionuclides and the dose from penetrating radiation from sources external to the body. This is a risk-equivalent value and can be used to estimate the health-effects risk to the exposed individual.

- *Total effective dose equivalent*—includes the sum of the effective dose equivalent (for external exposures) and the CEDE (for internal exposures). For purposes of compliance, dose equivalent to the whole body may be used as the effective dose equivalent for external exposures.

Table 6.1 shows internal dose factors for several radionuclides of interest at the Paducah Site. These factors are used to determine the CEDE to an adult.

Direct Radiation

In 1999, DOE conducted continuous monitoring for direct external radiation exposure (Section 5). The monitoring results indicate that, due to inaccessibility of the public to radioactive source areas, the dose to the maximally exposed individual member of the public (i.e., the neighbor living closest to the PGDP security fence) from DOE operations did not vary statistically from background (i.e., was essentially zero) (BJC 2000b).

For purposes of this annual environmental report, an additional potential receptor was considered. This receptor is assumed to frequently travel along Dyke Road in the vicinity of location TLD-25 (Figure 5.4). A very conservative exposure scenario assumes occupancy for the maximally exposed receptor at this location in 1999 to be 100 hours based on an individual driving past this location twice per day at 12 minutes per trip, five days per week, 50 weeks per year. The mean dose rate for location TLD-25, attributable to the Paducah Site, was determined to be 0.00137 mrem/hr (BJC 2000b). Therefore, the dose to this receptor is calculated at 0.137 mrem for 1999. It is worth noting that actual occupancy at this location is probably very less than assumed and that any shielding from the receptor's vehicle is not considered. Furthermore, even if the receptor were assumed to have occupied this site for 365 days, 24 hours per day in 1999, the total dose received would have been approximately 12 mrem, well below the DOE 100 mrem limit to members of the public.

Surface Water

The most common surface water pathway for exposure is through drinking water containing radionuclides. A drinking water pathway dose was calculated in 1999 for an individual assumed to consume water from the public drinking water supply at Cairo, Illinois. Cairo is the closest drinking water system that uses water downstream of PGDP effluents. Stream concentrations of radionuclides were

Table 6.1 Internal Dose Factors for an Adult

		Intake[a] (mrem/pCi)			
Isotope	**Half-life (years)**	**Inhalation (soluble)**	**Inhalation (slightly soluble)**	**Inhalation (insoluble)**	**Ingestion**
^{234}U	240,000	0.0027	0.0071	0.13	0.00026
^{235}U	710,000,000	0.0025	0.0067	0.12	0.00025
^{238}U	4,500,000,000	0.0024	0.0062		0.00023
^{99}Tc	210,000	0.00000084	0.0000075	0.12	0.0000013
^{237}Np	2,100,000		0.49		0.0039
^{239}Pu	24,000		0.51	0.33	0.0043
^{230}Th	75,000		0.32	0.26	0.00053

[a] Source: U.S. DOE. July 1988. *Internal Dose Conversion Factors for Calculations of Dose to the Public*, DOE/EH-0071.

measured in Bayou and Little Bayou creeks and, using dilution factors based on U. S. Geological Survey flow measurements, were used to calculate approximate radionuclide concentrations at the Cairo water intake. The additive dose from both creeks to the Cairo water system would have resulted in a dose to an individual user of approximately 0.00029 mrem in 1999. This is a very small dose; therefore, the surface water pathway is not considered as a significant contributor to the dose received by the maximally exposed individual from DOE sources at PGDP.

Contaminated Sediment

Exposure to contaminated sediment in Bayou and Little Bayou creeks could occur during fishing, hunting, or other recreational activities. Exposure is possible through incidental ingestion of contaminated sediment. The worst-case ingestion assumption is that an individual would splash around in one of the creeks every other day during the hunting season and ingest a small amount of sediment each visit. A dose is then calculated based on the radionuclide concentrations (Table 5.4) and amount of exposure via ingestion. Upstream samples are assumed to be background and are subtracted from downstream sample results to arrive at a dose associated with site releases. The downstream location with the maximum dose is assumed to represent the dose received from this pathway by the maximally exposed individual.

Table 6.2 shows the doses calculated for ingestion of sediments for both Bayou and Little Bayou creeks. For Little Bayou Creek, the worst-case dose was calculated at SS 2. For Bayou Creek, the worst-case dose was calculated at SS 1. The worst-case dose for Little Bayou Creek exceeds that for Bayou Creek. Therefore, the estimated worst-case dose above background from sediment ingestion that would have been received by an individual who was assumed to spend time in the WKWMA every other day during the hunting season would be 0.018 mrem in 1999. This 1999 dose is lower than the dose for 1998 and previous years due to the use of a smaller, more realistic ingestion rate.

Ingestion of Deer

The effect of an intake of a radionuclide by ingestion depends on the concentration of the radionuclide in food and drinking water and on the individual's consumption patterns. The estimated intake of a radionuclide is multiplied by the appropriate ingestion dose factor to provide the estimate of CEDE resulting from the intake.

Terrestrial wildlife, such as deer, can come into contact with contaminated soil, ingest plants that have taken up contaminants, or ingest contaminated water. Hunting is permitted in the WKWMA surrounding the Paducah Site, and the limit for deer harvest is two deer per person per season. Approximately 100 deer are harvested per year from WKWMA. The Paducah Site dose calculations assume that an individual kills two average-weight deer and consumes the edible portions of those deer during the year. The dose is calculated for each deer.

In 1999, eight deer from the Paducah Site were sampled along with two reference deer from the BWMA (Section 5). As a worst-case scenario for site dose contribution, it is assumed that a person kills and eats the two deer with the largest dose potential. The worst-case dose was calculated to be 2.70 mrem which is 0.53 mrem above average background dose. The highest dose estimate for a single deer was actually a background deer. Site deer are statistically within the range of doses calculated for background deer (Hampshire 1999).

Airborne Radionuclides

Emissions from DOE's only radionuclide airborne point-source discharge in 1999, the Northwest Plume Groundwater System, were monitored to determine the extent to which the general public could be exposed and to demonstrate compliance with EPA regulations Radiological Protection recommendations (ICRP 1979).

Table 6.2 Annual Dose Estimates for 1999 of Worst-Case Incidental Ingestion of Sediment from Little Bayou Creek and Bayou Creek

Analysis	Average Concentration (pCi/g)	Ingestion Rate (mg/d)	Frequency (days)	Total Intake (pCi)	Ingestion Dose Conversion Factor (mrem/pCi)	CEDE (mrem)	Total for Location (mrem)
Downstream Bayou Creek (SS1)							
Neptunium-237	0.00088	50	106	0.00466	0.00390	0.0000182	
Plutonium-239/240	0.0286	50	106	0.152	0.00430	0.000651	
Technetium-99	0.999	50	106	5.29	0.000130	0.000688	
Thorium-230	0.161	50	106	0.856	0.000530	0.000454	
Uranium-234	0.545	50	106	2.89	0.000260	0.000751	
Uranium-235	0.030	50	106	0.159	0.000250	0.0000398	
Uranium-238	0.854	50	106	4.53	0.000230	0.00104	0.00364
Downstream Little Bayou Creek (SS2)							
Neptunium-237	0.0130	50	106	0.0689	0.00390	0.000269	
Plutonium-239/240	0.00938	50	106	0.0497	0.00430	0.000214	
Technetium-99	17.9	50	106	94.6	0.000130	0.0123	
Thorium-230	0.247	50	106	1.31	0.000530	0.000694	
Uranium-234	0.650	50	106	3.44	0.000260	0.000896	
Uranium-235	0.069	50	106	0.366	0.000250	0.0000914	
Uranium-238	4.66	50	106	24.7	0.000230	0.00568	0.0201
Upstream Bayou Creek (SS20)							
Neptunium-237	-0.00512	50	106	-0.0271	0.00390	-0.000106	
Plutonium-239/240	0.00105	50	106	0.00557	0.00430	0.0000239	
Technetium-99	0.312	50	106	1.66	0.000130	0.000215	
Thorium-230	0.124	50	106	0.657	0.000530	0.000348	
Uranium-234	0.230	50	106	1.22	0.000260	0.000317	
Uranium-235	0.012	50	106	0.0636	0.000250	0.0000159	
Uranium-238	0.257	50	106	1.36	0.000230	0.000313	0.00113
Upstream Little Bayou Creek (SS21)							
Neptunium-237	0.0254	50	106	0.135	0.00390	0.000525	
Plutonium-239/240	0.0110	50	106	0.0583	0.00430	0.000251	
Technetium-99	0.461	50	106	2.44	0.000130	0.000318	
Thorium-230	0.145	50	106	0.768	0.000530	0.000407	
Uranium-234	0.170	50	106	0.901	0.000260	0.000234	
Uranium-235	0.009	50	106	0.0477	0.000250	0.0000119	
Uranium-238	0.247	50	106	1.31	0.000230	0.000301	0.00205
Downstream Little Bayou Creek (SS27)							
Neptunium-237	0.0376	50	106	0.199	0.00390	0.000777	
Plutonium-239/240	0.0897	50	106	0.475	0.00430	0.00204	
Technetium-99	4.00	50	106	21.2	0.000130	0.00276	
Thorium-230	1.08	50	106	5.72	0.000530	0.00303	
Uranium-234	1.59	50	106	8.48	0.000260	0.00219	
Uranium-235	0.096	50	106	0.509	0.000250	0.000127	
Uranium-238	3.34	50	106	17.7	0.000230	0.00407	0.0150
Reference Site Massac Creek (SS28)							
Neptunium-237	0.00333	50	106	0.0176	0.00390	0.0000688	
Plutonium-239/240	-0.0007	50	106	-0.00378	0.00430	-0.0000162	
Technetium-99	0.187	50	106	0.991	0.000130	0.000129	
Thorium-230	0.0248	50	106	0.131	0.000530	0.0000697	
Uranium-234	0.062	50	106	0.329	0.000260	0.0000854	
Uranium-235	0.003	50	106	0.0159	0.000250	0.00000398	
Uranium-238	0.07	50	106	0.371	0.000230	0.0000853	0.000426

Calculation of CEDE above background at creek location:

Big Bayou downstream (SS1) - Big Bayou upstream (SS20) = 0.00252 mrem

Little Bayou downstream (SS2) - Little Bayou upstream (SS21) = 0.0181 mrem

Total calculated estimate of CEDE from sediment ingestion: 0.00252 + 0.0181 = 0.0206 mrem

The 50-year CEDE (internal) from DOE air sources to the maximally exposed individual, who under most circumstances is the person living closest to the plant in the predominant wind direction, is calculated each year. The maximally exposed individual for 1999, identified through modeling, is located approximately 1080 meters (3543 ft) north-northeast of the plant site. The dose to the maximally exposed individual from radioactive emissions was calculated to be 1.7×10^{-3} (0.0017) mrem which is well below the 10-mrem limit of 40 CFR Part 61, Subpart H.

Conclusions

Table 6.3 provides a summary of the dose for 1999 from the Paducah Site that could be received by a member of the public assuming worst-case exposure from all major pathways. The largest contributor to the calculated dose is from ingestion of deer meat. The groundwater pathway from DOE sources is assumed to contribute no dose to the population because all residents have been supplied with public water by DOE. The worst-case combined (internal and external) dose to an individual member of the public was calculated at 0.69 mrem. This level is well below the DOE annual dose limit of 100 mrem/year to members of the public and below the EPA limit of 10 mrem.

Estimates of radiation doses presented in this report were calculated using the dose factors provided by DOE and EPA guidance documents. These dose factors are based on International Commission on Radiological Protection Publication 30, *Limits of Intakes of Radionuclides by Workers* (ICRP 1979). Figure 6.3 shows the potential (worst-case) annual dose as calculated for the past five years.

Table 6.3 Summary of Potential Radiological Dose from the Paducah Site for 1999 (Worst-Case Combined Exposure Pathways)

	Dose[a] (mrem/year)	Percent of total
Ingestion of surface water	0.00029	<1
Ingestion of sediments	0.0206	3
Ingestion of deer meat	0.53	77
Direct radiation	0.137	20
Atmospheric releases	0.0017	<1
Total annual dose above background (all pathways)	**0.69**[b]	**100**

[a] 100 mrem = 1 mSv

[b] Maximum allowable exposure is 100 mrem/year (DOE Order 5400.5)

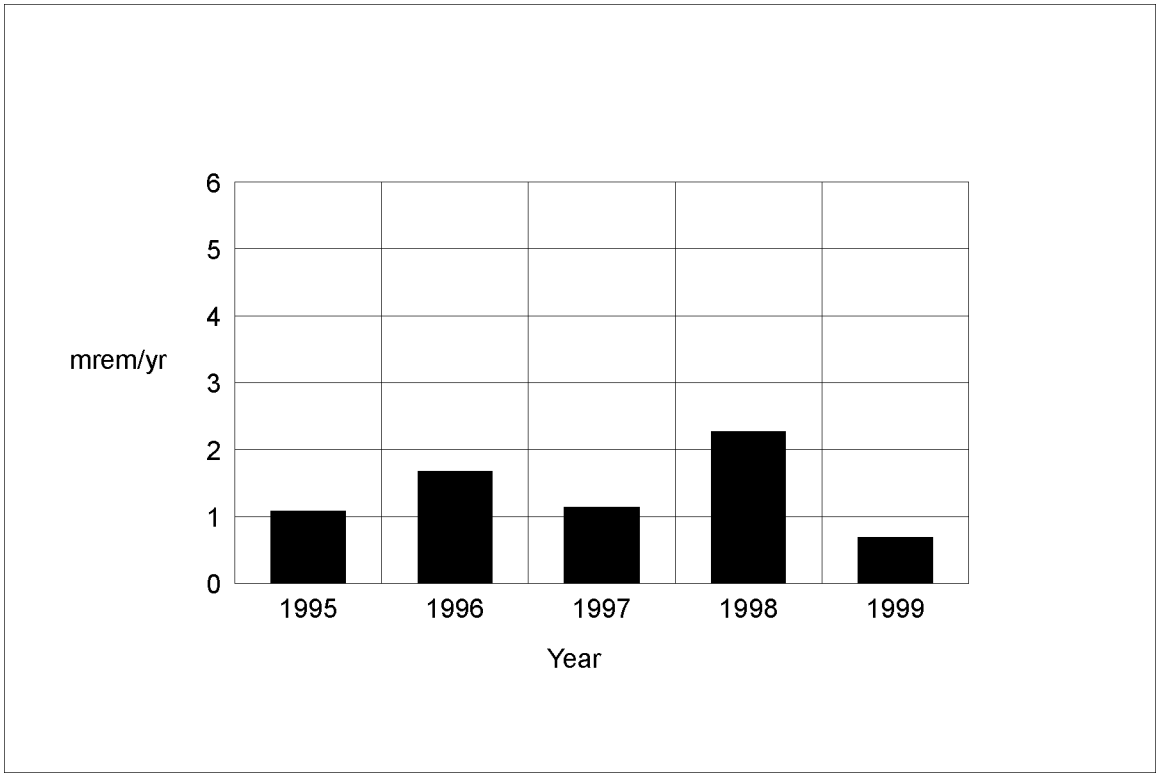

Figure 6.3 Potential radiological dose from the Paducah Site, 1995 thru 1999.

7 Nonradiological Effluent Monitoring

Abstract

Effluents are gaseous or liquid waste discharges to the environment. Monitoring effluents assures compliance with applicable release standards established by federal and state regulations. Effluent monitoring consists of the collection and analysis of samples or measurements of liquid, gaseous, or airborne effluents. The monitoring determines and quantifies contaminants and process-stream characteristics, assesses any chemical or radiological exposures to members of the public or the environment, and demonstrates compliance with applicable standards. Monitoring effluents is necessary to determine the effects emissions may have on the public and the surrounding environment.

In 1999, there were two KPDES outfalls at the Paducah Site that experienced exceedences for toxicity. Outfall 017 and Outfall 001 exceeded reportable KPDES effluent discharge permit limits for acute toxicity and chronic toxicity, respectively. An NOV was issued November 23, 1999, for Outfall 001 due to permit exceedences.

In 1999, DOE had two point sources for DOE air emissions. The combined emissions from these DOE sources were small; therefore, the Paducah Site is considered a minor source in accordance with the CAA.

Introduction

Responsibility for nearly all nonradioactive airborne emission sources at the PGDP was turned over to USEC as a result of the 1993 lease agreement between USEC and DOE. Only a few fugitive sources such as gravel roads, dirt piles (resulting from construction excavation), and metal scrap pile windage and two point sources remained the responsibility of DOE in 1999. The small amount of emissions from DOE sources results in CAA classification of the Paducah Site as a minor air emissions source.

Monitoring of nonradiological parameters in liquid effluents is summarized in the *Paducah Site Environmental Monitoring Plan* (BJC 1998) and is based on KPDES Permit No. KY0004049, and KDWM landfill permits 073-00014, 073-00015, and 073-00045. Effluents are monitored for nonradiological parameters listed on the permit governing the discharge.

Airborne Effluents

Airborne Effluent Applicable Regulations

The CAA at the Paducah Site is administered by KDAQ. DOE has responsibility only for air emission sources under DOE program control; therefore, this report does not address emissions from the PGDP sources leased to USEC.

Airborne Effluent Monitoring Program

The two point sources of air emissions for the Paducah Site in 1999 were the Northwest Plume Groundwater System and the Northeast Plume Containment System. These systems combined removed 2,676 pounds (1.3 tons) of TCE (a VOC) from the groundwater. These facilities remove TCE contamination from the groundwater by air stripping. At the Northwest Plume Groundwater System, TCE-laden air passes through carbon filtration which removes much of the TCE. The air stream is then released to the atmosphere where the remaining TCE naturally breaks down.

The CAA defines VOC emissions as criteria pollutants. A minor source is limited to 100 tons per year of each criteria pollutant. If greater quantities of criteria pollutants are emitted, then the source is classified as a major source. A minor source has less stringent permit requirements because of the reduced potential for health effects from the smaller amount of emissions.

The CAA also limits the emissions from a minor source of hazardous air pollutants (HAPs) to 10 tons/ year for each individual pollutant and 25 tons/year for all HAPs combined. TCE is a HAP. The greatest amount of HAP emitted in 1999 was less than the 2,676 pounds (1.3 tons) of TCE removed from the groundwater from the combination of the Northwest Plume Groundwater System and the Northeast Plume Containment System.

Liquid Effluents

Liquid Effluent Applicable Regulations

The CWA is administered for the Paducah Site by KDOW through the KPDES Wastewater Discharge Permitting Program. The sitewide KPDES permit (KY0004049) became effective April 1, 1998, and will expire on March 31, 2003. This permit contains limits based on water quality criteria for a zero-flow receiving stream.

KDWM specifies in landfill permits 073-00014, 073-00015, and 073-00045 that surface runoff be analyzed to ensure that landfill constituents are not discharging into nearby receiving streams.

Liquid Effluent Monitoring Program

DOE conducts nonradiological effluent monitoring for outfalls under its jurisdiction (Figure 4.1). Outfalls, 001, 015, 017, and 019 were monitored for KPDES permit parameters. *Title 40, Code of Federal Regulations, Part 136* (40 CFR 136), lists the specific sample collection, preservation, and analytical methods acceptable for the types of pollutants analyzed. Preservation in the field is conducted per 40 CFR 136, and chain-of-custody procedures are followed after collection and during transport to the analytical laboratory. The samples are then accepted by the laboratory and analyzed per 40 CFR 136 procedures for the parameters required by the KPDES permit.

Surface runoff from the closed C-746-S residential landfill, the closed C-746-T inert landfill, and the operating C-746-U landfill was monitored quarterly. Grab samples were monitored for chloride, sulfate, pH, sodium,

uranium, iron, total organic carbon, total suspended solids, total dissolved solids, and specific conductivity. The samples taken include landfill runoff, the receiving ditch upstream of the runoff discharge point, and the receiving ditch downstream of the runoff discharge point (Figure 4.2). Sampling was performed to comply with KDWM requirements for operation of the contained landfill.

Liquid Effluent Monitoring Results

Analytical results are reported to KDOW in monthly and quarterly discharge monitoring reports. Five exceedences of permit limits were reported in 1999 for DOE Outfalls 001 and 017 (Table 7.1 and Section 2).

Additional data is provided in Appendix C.

Outfall 001

Two noncompliances with KPDES parameters were reported in 1999 at Outfall 001. The noncompliances were for chronic toxicity of samples collected at the outfall. A TRE showed the toxicity to be from a fish pathogen (Section 2).

Outfall 017

Three noncompliances with KPDES parameters were reported in 1999 at Outfall 017. The noncompliances were for acute toxicity of samples collected at the outfall. A TRE indicated that the most likely source of the toxicity was from zinc washing off newly painted cylinders in DOE cylinder storage yards. The painting operation was ceased in 1998 and not resumed in 1999 because of the toxicity problems associated with painted cylinders. More detailed information is available in Section 2.

Table 7.1 KPDES Permit Exceedence Summary for 1999

Outfall	Noncompliance Parameter	Date Sampled	Result	KPDES Limit
017	Acute Toxicity	1st Quarter	1.41 TUa	1.0 TUa
017	Acute Toxicity	2nd Quarter	1.06 TUa	1.0 TUa
017	Acute Toxicity	December	3.89 TUa	1.0 TUa
001	Chronic Toxicity	2nd Quarter	3.32 TUc	1.0 TUc
001	Chronic Toxicity	December	1.4 TUc	1.0 TUc

8 Nonradiological Environmental Surveillance

Abstract

The nonradiological environmental surveillance program at the Paducah Site assesses the effects of DOE operations on the site and the surrounding environment. Surveillance includes analyses of air, surface water, groundwater (Section 9), sediment, soil, vegetation, terrestrial wildlife, and fish and other aquatic life. Surveillance results for 1999 were similar to results reported in previous ASERs.

Introduction

Nonradiological environmental surveillance at the Paducah Site involves sampling and analysis of surface water, groundwater (see Section 9 for groundwater surveillance results), sediment, soil, terrestrial wildlife, and fish and other aquatic life. This section discusses the results of surveillance activities.

Ambient Air

As a result of the transfer of the production part of the plant to USEC in 1993, major air emission sources were transferred to USEC. Therefore, the Paducah Site is not required to conduct ambient air monitoring for nonradiological parameters.

Surface Water

Surface water monitoring downstream of KPDES outfalls is not required by the KPDES permit. However, it is performed at the Paducah Site as part of the environmental surveillance program. The net impact of the Paducah Site's activities on surface waters is evaluated by comparing data from samples collected at reference locations (Massac Creek and the Ohio River) and locations upstream and downstream of PGDP at Little Bayou Creek and Bayou Creek (Figure 8.1). No sample point exists for upstream Little Bayou Creek as the watershed is insufficient to develop adequate flow to monitor. Most water in Little Bayou Creek is comprised of discharges from plant outfalls. Background water quality is derived from upstream Bayou Creek (L 1). L 29 and L 64 are reference waterways also used for comparisons with data for Bayou and Little Bayou creeks.

Bimonthly surface water samples had been collected at six locations (L 1, L 5, L 10, L 11, L 29, and L 64). In 1999, L 30 (Ohio River

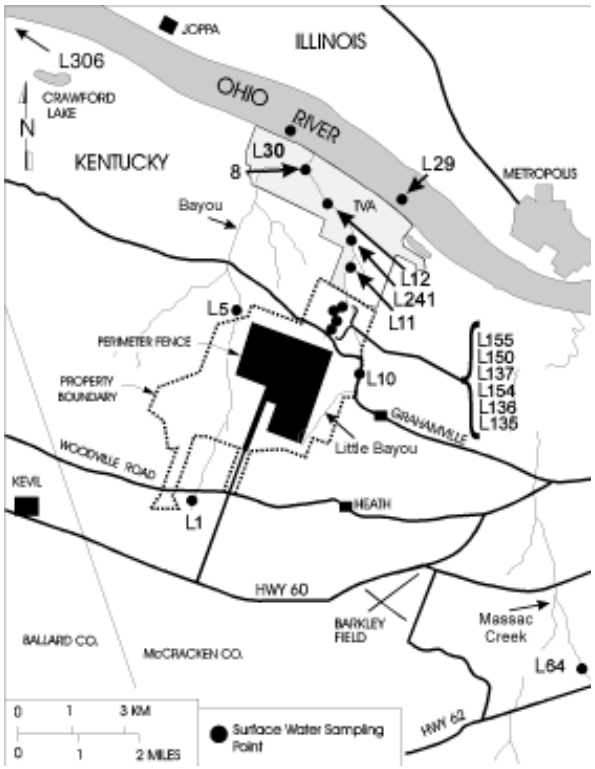

Figure 8.1 Surface water monitoring locations at the Paducah Site.

downstream of plant effluents) and L 306 (confluence of the Ohio and Mississippi Rivers at Cairo, Illinois) were added. Nonroutine samples were also collected at other locations as needs dictated. The bimonthly samples were analyzed for water quality parameters such as VOCs, selected radionuclides, and dissolved metals. The data can be used to compare upstream and downstream locations around the Paducah Site.

Surface Water Surveillance Results

Table 8.1 shows average concentrations for parameters where upstream and downstream results differed noticeably. Only one sample of the eight samples collected had a detectable concentration of acetone. L 12 and L 241 had TCE concentrations of 4 mg/L and 34 mg/L, respectively. These stations are located in Little Bayou Creek downstream of L 10 (Figure 8.1). Recharge of the creek from the Northeast Groundwater Plume is believed to be responsible for the TCE found at these locations. A detectable concentration of TCE was also seen at L 1. The data also shows acetone present at L 5.

Chloride at the Bayou Creek downstream location was higher than at the upstream site. The highest concentrations of suspended solids and iron were found in the Ohio River. Uranium was also detected at low concentrations in all downstream creek locations.

The results for the receiving creeks can be compared to the Paducah Site's KPDES permit standards which are based on warm water aquatic habitat criteria established by KDOW (401 KAR 5:031). All sample results for Bayou and Little Bayou creeks are within KPDES standards.

Surface water samples are also taken on a quarterly basis at the C-746-S&T closed landfills. Samples are taken upstream of surface runoff from the landfill, at the landfill, and downstream of the landfill. Data is reported quarterly to KDWM. Appendix C provides the results of surface water monitoring. Figure 8.1 shows monitoring locations.

Additional surface water data can be found in Appendix C.

Sediment

Sediment is an important constituent of the aquatic environment. If a pollutant is a suspended solid or is attached to suspended sediment, it can settle to the bottom (thus creating the need for sediment sampling), be taken up by certain organisms, or become attached to plant surfaces. Pollutants in solution can adsorb on suspended organic and inorganic solids or be assimilated by plants and animals. Suspended solids, dead biota, and excreta settle to the bottom and become part of the organic substrata that support the bottom-dwelling community of organisms. Sediments play a

Table 8.1 Selected Routine Nonradiological Surface Water Surveillance Results (mg/L Average Concentrations)

Parameter	L 1 Upstream Bayou	L 5 Down-stream Bayou	L 10 Down-stream Little Bayou	L 11 Down-Stream Little Bayou	L 29 Upstream Ohio River	L 30 Down-stream Ohio River	L 64 Massac Creek	L 306 Down-stream Ohio River (Cairo, IL.)
Acetone	ND	<860	ND	ND	ND	ND	ND	ND
Aluminum	ND	ND	1.15	<0.69	1.22	0.51	ND	0.26
Chloride	15.5	75.6	31.1	30.9	18.0	25.3	13.7	28.5
Iron	0.43	0.27	0.8	0.61	0.96	0.55	0.84	<0.27
Suspended Solids	ND	10	13	ND	26	19	ND	<10
TCE	<1	ND	ND	ND	ND	ND	ND	ND
Uranium	ND	0.04	0.01	0.005	ND	ND	ND	ND

ND = not detected

significant role in aquatic ecology by serving as a repository for radioactive or chemical substances that pass via bottom-feeding biota to the higher trophic levels. Figure 5.2 shows possible exposure routes of trace metals (including uranium) in an aquatic ecosystem.

Sediment Surveillance Program

As a result of DOE's retaining responsibility for historic environmental problems, ditch sediments are sampled annually as part of a nonradiological environmental surveillance program. Sediment samples were taken from eight locations in 1999 (Figure 5.3). Sediments were sampled for metals and PCBs.

Sediment Surveillance Results

Table 8.2 shows average concentrations for parameters where upstream and downstream results differed noticeably. Bayou Creek downstream results show a slight decrease in some metals from upstream samples whereas Little Bayou Creek downstream results show a increase or no significant difference in upstream concentrations for most metals. A notable exception is chromium which shows a large

Table 8.2 Selected Routine Nonradiological Sediment Surveillance Results (mg/kg)

Parameter	SS 20 Upstream Bayou	SS 1 Downstream Bayou	SS 21 Upstream Little Bayou	SS 2 Downstream Little Bayou	SS 27 Downstream Little Bayou	SS 28 Massac Creek
Aluminum	4120	3415	4640	3670	1010	491
Chromium	47.3	9.18	7.10	38.9	107	2.35
Iron	29800	8545	9690	27300	9760	1440
Vanadium	42.4	13.6	16.9	39.2	26.9	2.84
Zinc	26.5	17.2	16.3	44.2	29.6	15.0

increase in one Little Bayou Creek downstream location.

PCBs were not detected at any locations. This differs from previous years where PCBs were found at up to 2.0 µg/g at SS 2 as recently as 1993. Due to data from past studies in which PCBs were detected, signs were posted at Little Bayou Creek to make the public aware of potential PCB contamination. Continued surveillance for several more years is necessary to identify any significant change from past trends.

Additional sediment data can be found in Appendix C.

Soil

The major source of soil contamination is from air pathways. Because DOE no longer controls any major air emissions sources, routine soil surveillance is not performed. However, surface soil contamination is being addressed by the Surface Soils Operable Unit (see Environmental Restoration Program discussion in Section 3).

Vegetation

Because DOE no longer operates any major air emissions sources, routine vegetation surveillance activities are not performed.

Fish and Other Aquatic Life

The watershed (biological) monitoring discussed in this report was conducted under DOE Order 5400.1 and KPDES Permit No. KY0004049. The KPDES Permit also requires toxicity monitoring of one continuous outfall and of three intermediate outfalls on a quarterly basis. Watershed monitoring of Bayou and Little Bayou creeks has been conducted since 1987 (Figure 8.2).

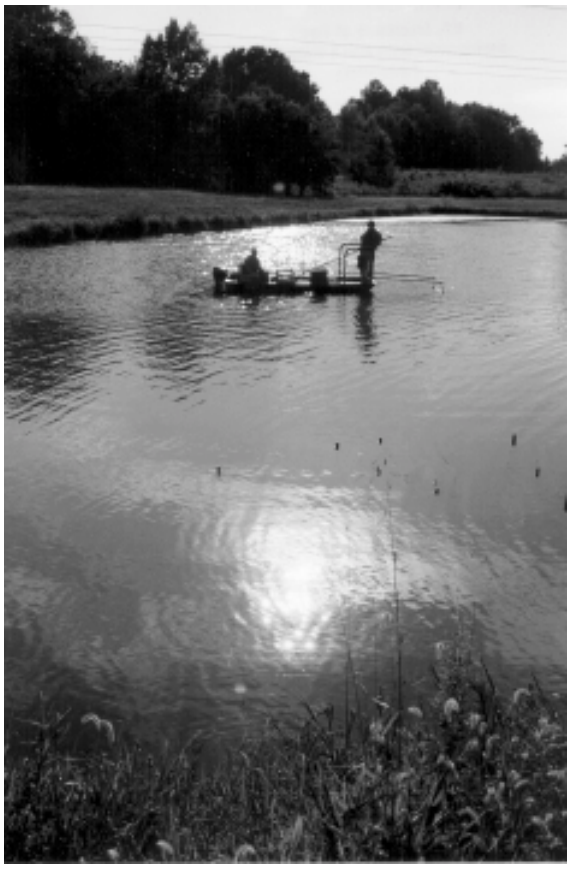

Figure 8.2 Collecting fish samples.

The objectives of the revised Watershed Monitoring Program are as follows:

- determine whether discharges from the Paducah Site and the SWMUs associated with the Paducah Site are adversely affecting instream fauna;
- assess the ecological health of Little Bayou and Bayou creeks;
- assess the degree to which abatement actions ecologically benefit Bayou and Little Bayou creeks;

- provide guidance for remediation;
- provide an evaluation of changes in potential human health concerns; and
- provide data which could be used to assess the impact of inadvertent spills or fish kills.

The 1999 sampling effort was conducted in accordance with the *Bayou Creek and Little Bayou Creek Watershed Monitoring Program* (Kszos, et al 1998), otherwise known as the PGDP Watershed Monitoring Program Plan, which was approved by KDOW as a result of the KPDES permit.

Study Area

As specified by the PGDP Watershed Monitoring Program Plan, the fish and benthic macroinvertebrate communities were sampled only during one time period in the fall at the following locations: Bayou Creek (BBK 12.5, BBK 10.0, and BBK 9.1), Little Bayou Creek (LUK 7.2), and Massac Creek (MAK 13.8). Sampling locations are shown in Figure 8.3. The bioaccumulation of PCBs in fish were monitored by collecting longear sunfish at three location in Little Bayou Creek (LUK 9.0, LUK 7.2, and LUK 4.3) and by collecting spotted bass from one location in Bayou Creek (BBK 10.0). Massac Creek serves as the source of background fish (MAK 13.8).

Benthic macroinvertebrate samples were collected with a Surber square-foot bottom sampler from randomly selected locations within a designated riffle at each of the five sites. Samples were processed in a laboratory following standard operating procedures (SOPs). Organisms were identified to the lowest practical taxon and enumerated. Instream and riparian habitat, and water quality, were assessed at each site following standard procedures outlined by EPA. An analysis of the data includes general descriptive and parametric statistics to evaluate trends in temporal and spatial changes that could be associated with abatement activities or remedial actions. Metrics of the benthic macroinvertebrate community such as total density, total taxonomic richness, taxonomic richness of the pollution-sensitive Ephemeroptera, Plecoptera, and Trichoptera (EPT), percent community similarity index, and dominants in common are included in the analysis of the data.

Quantitative samplings of the fish communities at the five sites in the Paducah Site area were conducted by electrofishing. Eight-m to 120-m reaches of each site were sampled using a three-pass removal estimate with block-nets defining the sample reach. Data from these samples were used to estimate species richness, population size (numbers and biomass per unit area), and annual production. Data were adapted to create an Index of Biotic Integrity that is consistent with KDOW 1986 guidelines. All fish sampling sites overlap sites used in the benthic macroinvertebrate community task. All field sampling was conducted according to SOPs.

The concentration of PCBs in fish was determined in longear sunfish (*Lepomis megalotis*) from the Little Bayou Creek sites and spotted bass *(Micropterus punctulatus*) from Bayou Creek. Filets of individual sunfish and composited filet samples of the spotted bass were analyzed for PCBs. PCB analyses were conducted using Soxhlet extraction techniques according to SW-846 Method 3540 and analysis by capillary column gas chromatography using SW-846 Method 8080. In addition to blanks and laboratory control standards, standard reference materials, and/or spike samples of fish known to be uncontaminated were run to demonstrate recovery of the analytes. Fish from background reference sites were also analyzed with each submission to demonstrate the absence of false positives or interferences, and establish background levels.

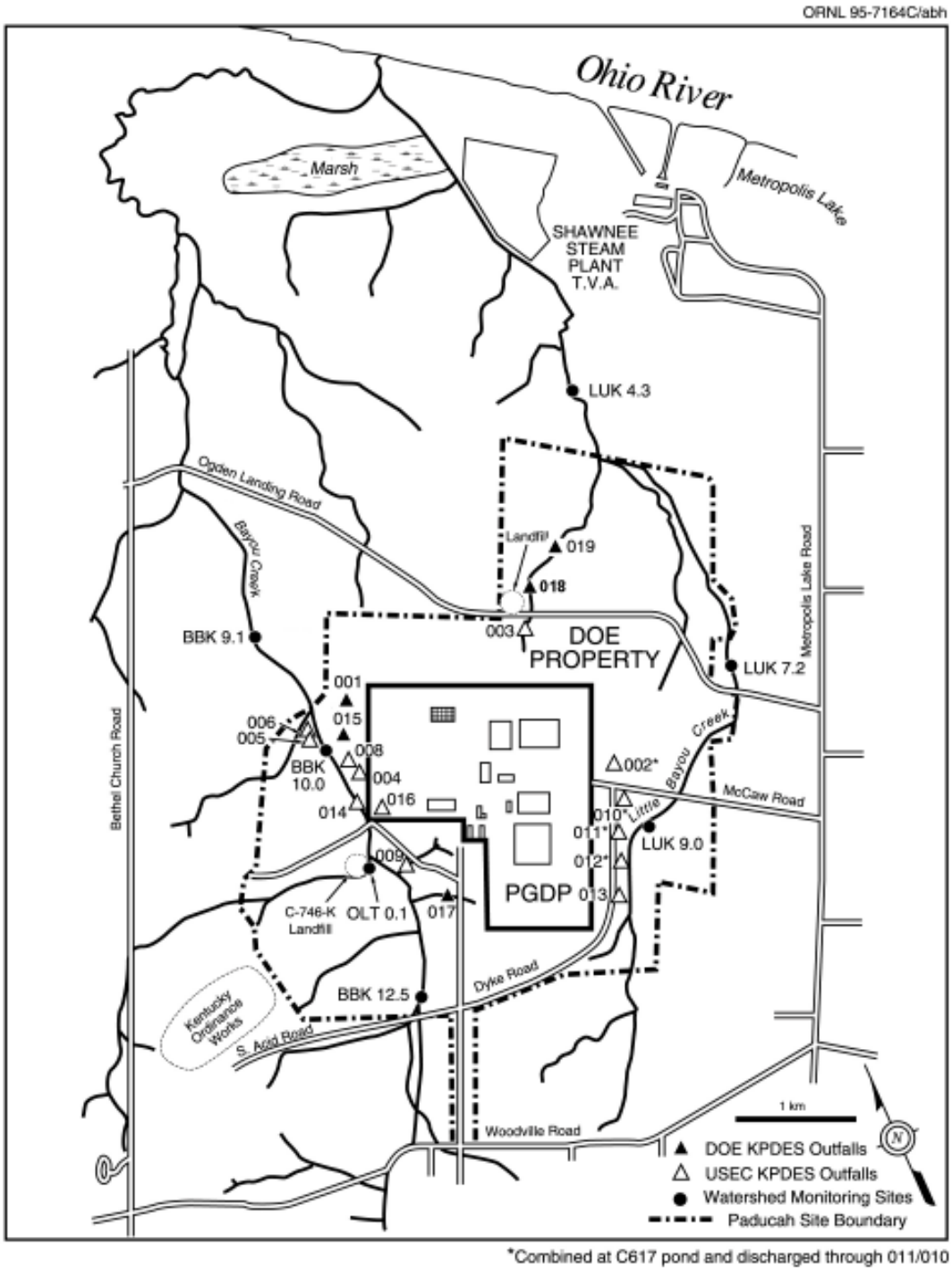

Figure 8.3 Biological monitoring sampling locations.

Watershed Monitoring

A detailed Watershed Monitoring Report is generated on an annual basis in accordance with the approved Watershed Monitoring Program Plan. Sampling for the 1999 report was completed during the month of September. The 1999 report concluded that historical contamination from PGDP is detectable as fish in Bayou and Little Bayou creeks continue to have elevated PCB levels in tissue (CDM 2000). These levels, however, are on the decline based on PCB levels in fish tissue data that have been

collected from 1990 to 1999. These data were reported annually from 1990 to 1998 by the Oak Ridge National Laboratory in an annual report entitled *Report on the Biological Monitoring Program at the Paducah Gaseous Diffusion Plant* (Kszos 1994a, 1994b, 1996a, 1996b, 1997, 1998, and 1999). A concern is the relative high concentrations found in fish collected during the 1998 sampling effort. Levels observed for 1999 sampling were reduced, but other parameters of the fish communities examined were different than that seen in previous years.

Macroinvertebrate fauna were significantly different in the downstream sampling sites as compared to the upstream (BBK 12.5) and reference (MAK 13.8) sites. Although these differences could not be directly attributed to contaminant discharge from the PGDP, future sampling will be evaluated to include a downstream macroinvertebrate sample on Massac Creek. Such a site may clarify whether changes in the macroinvertebrate fauna are due to PGDP discharge or the fact that the sites are associated with the Ohio River floodplain and thus, are ecologically different.

The ecological health, based on macroinvertebrate and fish faunas, of Little Bayou and Bayou creeks is of concern. Significant differences were noted in the macroinvertebrate fauna and significant declines in the fish density and biomass were recorded for BBK 12.5 and LUK 7.2. Of importance is the fact that all sites show continued species diversity, but the density reductions at BBK 12.5 and LUK 7.2 should remain a concern. Biomass reductions at all of the sites sampled suggest that an ecological event(s) probably accounts for the observed declines, but recovery on the reference and PGDP-influenced creeks needs to be monitored closely. An occurrence of an ecological event could be due in part to the severe drought western Kentucky experienced during the summer and early fall of 1999.

Bioaccumulation of PCBs in fish tissue has declined in recent years, suggesting decreased PCB levels from the Paducah Site KPDES outfalls. Levels of bioaccumulation of PCBs recorded during 1999 are still of biological significance. Therefore, concern still exists for the possible release of PCBs and other toxicants (metals and radionuclides) during major rainfall events. Continued implementation of erosion control measures around the site will reduce the likelihood of the additional release of PCBs during major rainfall events. A summary of the mean concentration of PCBs in fish fillets sampled in Bayou and Little Bayou Creeks as well as the reference location in Massac Creek are provided in Table 8.3.

Toxicity Monitoring

The toxicity of effluents from the continuously flowing Outfall 001 and intermittently flowing Outfalls 015, 017, and 019 were monitored using water fleas (*Ceriodaphnia dubia*) and fathead minnow (*Pimephales promelas*) larvae. Toxicity tests were conducted quarterly as required by the KPDES permit. Short-term 48-hour toxicity tests

Table 8.3 Average Concentration of PCBs (µg/g wet weight) in Filets of Fish from Streams near the Paducah Site, April and October 1999

Site[a]	Species[b]	Mean[c]	Range	n
BBK 10.0	Spotted bass	0.12	0.12	1
LUK 9.0	Longear sunfish	0.24	0.10-0.60	6
LUK 7.2	Longear sunfish	0.13	<0.05-0.24	6
LUK 4.3	Longear sunfish	<0.05	N/A	4
MAK 13.8	Longear sunfish	<0.05	N/A	6

a BBK = Big Bayou Creek kilometer; LUK = Little Bayou Creek kilometer; MAK = Massac Creek kilometer

b Spotted bass = *Micropterus punctulatus;* Longear sunfish = *Lepomis megalotis;* Redbreast sunfish = *Lepomis auritus*

c Value of ‰the detection limit was used in calculating means for samples

(also known as an acute test) were conducted for Outfalls 015, 017, and 019, and longer term 6- or 7-day toxicity tests (also known as a chronic test) were conducted for Outfall 001. For the acute toxicity test data, the 48-hour LC_{50} (concentration that is lethal to 50% of the test organisms) was determined and the acute toxicity unit (TU_a) was calculated ($TU_a = 100/LC_{50}$). For the chronic toxicity test data, the 25% inhibition concentration (IC25, that concentration causing a 25% reduction in fathead minnow growth *Ceriodaphnia* reproduction compared to a control) was determined and the chronic toxicity unit (TU_c) was calculated ($TU_c = 100/IC25$). The TU_a and TU_c are compliance endpoints in the KPDES permit. For permitting purposes, KDOW has determined that Little Bayou and Bayou creeks have a low-flow zero; thus a TU > 1.0 would be considered a noncompliance and an indicator of potential instream toxicity. A TU $\geq$ 1.2 is considered a significant noncompliance.

During 1999, five toxicity exceedences were noted at KPDES Outfall 017. Details are provided in Sections 2 and 7 of this ASER.

Terrestrial Wildlife

Annual Deer Harvest

The deer population in WKWMA is sampled annually to determine levels of radionuclides (Section 5), PCBs, and inorganic elements that might be attributed to past plant practices. There were eight deer harvested from WKWMA and two deer harvested from the BWMA to serve as reference samples. There were no PCBs detected in the fat tissue, muscle, or liver samples of any of the ten deer harvested. Of the inorganics detected, all results for the WKWMA deer were comparable to the reference deer except for the presence of small amounts of barium, nickel, and copper in the liver of some WKWMA deer. Silver was found to be elevated in the muscle of a WKWMA deer and nickel was found elevated in another WKWMA deer. Beryllium, iron, vanadium, and zinc were found elevated in the muscle of background (Tables 8.4 and 8.5).

In summary, there were no unusual findings in the 1999 deer data. When comparing Paducah Site deer data to the reference deer data, the results were not substantially different. The data from future sampling events will continue to be assessed to identify any potential trends.

Additional data is provided in Appendix C.

Non-Routine Rabbit Sampling

At the request of KDFWR, rabbit sampling was conducted in 1999. Muscle and fat tissue from seven rabbits collected at WKWMA were sampled for radionuclides (Section 5), PCBs, and inorganic elements. No PCBs were detected in any samples. Copper, aluminium, iron, manganese, and zinc were detected in several muscle samples and barium was detected in one muscle sample. No regulatory standards exist by which to compare these results.

Additional data is provided in Appendix C.

Table 8.4 Analytical Detects in Deer Liver Tissue for 1999 (mg/kg)

	West Kentucky Wildlife Management Area									Ballard Wildlife Management Area	
Analysis	Deer 1	Deer 1 Dup	Deer 2	Deer 3	Deer 4	Deer 5	Deer 6	Deer 7	Deer 8	Deer 9	Deer10
Aluminum	3.66	4.16	4.44	4.21	11.2	23	4.25	3	2.6	3.6	2.82
Barium	0.471	0.403	0.799	0.534	0.734	1.27	0.216	0.139	ND	0.166	0.195
Cadmium	ND	0.341	ND	ND	0.415	ND	ND	0.271	ND	ND	ND
Copper	67.2	52.8	1.83	9.06	45.5	1.68	92.6	44.2	67.9	19.4	14.9
Iron	77.3	152	244	297	117	399	112	149	78.2	142	112
Manganese	3.51	4.31	0.474	1.68	4.14	0.369	5.9	4.11	4.32	4.84	3.9
Nickel	ND	14.2	1	ND	ND	ND	ND	ND	3.69	ND	ND
Vanadium	0.343	ND	0.321	ND	0.261	ND	ND	0.325	ND	ND	0.293
Zinc	37.1	38	26.8	25.1	41.6	19.9	36	37.7	40.3	35.1	37

Table 8.5 Analytical Detects in Deer Muscle Tissue for 1999 (mg/kg)

	West Kentucky Wildlife Management Area									Ballard Wildlife Management Area	
Analysis	Deer 1	Deer 1 Dup	Deer 2	Deer 3	Deer 4	Deer 5	Deer 6	Deer 7	Deer 8	Deer 9	Deer10
Aluminum	2.76	ND	ND	1.96	ND	5.37	3.03	ND	13.4	3.94	3.92
Barium	0.473	ND	ND	ND	ND	0.437	ND	ND	ND	ND	ND
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.019	ND
Copper	2	1.45	1.57	2.1	1.55	2.2	1.83	1.78	2.37	1.97	1.97
Iron	35.2	34.4	32.5	36.2	33.9	40.1	39.3	41	28.5	54.2	40.1
Manganese	0.133	0.095	0.111	0.175	0.11	0.285	0.205	0.207	0.192	0.245	0.223
Nickel	ND	ND	ND	ND	0.949	ND	ND	ND	1.49	ND	ND
Silver	ND	ND	ND	ND	1.7	ND	ND	ND	ND	ND	ND
Zinc	16.2	15.7	13	14.1	16.3	18.8	21.4	14.8	17.4	22	14.8

9 Groundwater

Abstract

The primary objectives of groundwater monitoring at the Paducah Site are to detect contamination and provide the basis for groundwater quality assessments if contamination is detected. Monitoring includes the exit pathways at the perimeter of the plant and off-site water wells. Primary off-site contaminants continue to be TCE, an industrial degreasing solvent, and ^{99}Tc, a fission by-product. Evidence suggests the presence of dense nonaqueous phase liquids (DNAPL) on-site.

Introduction

Monitoring and protection of groundwater resources at the Paducah Site are required by federal and state regulations and by DOE orders. Federal groundwater regulations generally are enacted and enforced by EPA. The Paducah Site lies within EPA Region IV jurisdiction. EPA Region IV encompasses the southeastern United States and maintains headquarters in Atlanta, Georgia. Many state groundwater regulations are enacted and enforced by KDWM in Frankfort, Kentucky. A KDWM field office for western Kentucky is located in Paducah.

When offsite contamination from the Paducah Site was discovered in 1988, the EPA and DOE entered into an ACO. DOE provided an alternate water supply to affected residences. Under CERCLA, DOE is also required to determine the nature and extent of offsite contamination through sampling of potentially affected wells and a comprehensive site investigation.

A CERCLA/ACO site investigation, completed in 1991, determined offsite contaminants in the RGA to be TCE, used as an industrial degreasing solvent, and ^{99}Tc, a fission byproduct contained in nuclear power reactor returns that were brought on-site several years ago for reenrichment. Such reactor returns are no longer enriched. Known or suspected sources of TCE and ^{99}Tc include burial grounds, former test areas and other facilities, spills, leaks, and leachate derived from contaminated scrap metal.

Investigations into the onsite source areas of TCE at the Paducah Site are ongoing. A common degreasing agent, TCE is considered a dense non-aqueous phase liquid (DNAPL). DNAPLs typically have low solubilities in water and sink to the bottom of aquifers or come to rest upon a less permeable layer within an aquifer, forming pools. These DNAPL pools form a continuing source for dissolved-phase contamination (plumes) that are migrating offsite toward the Ohio River (Figure 9.1). DNAPL pools are extremely difficult to clean up and currently only the highest concentrations of dissolved TCE are controlled by pump-and-treat

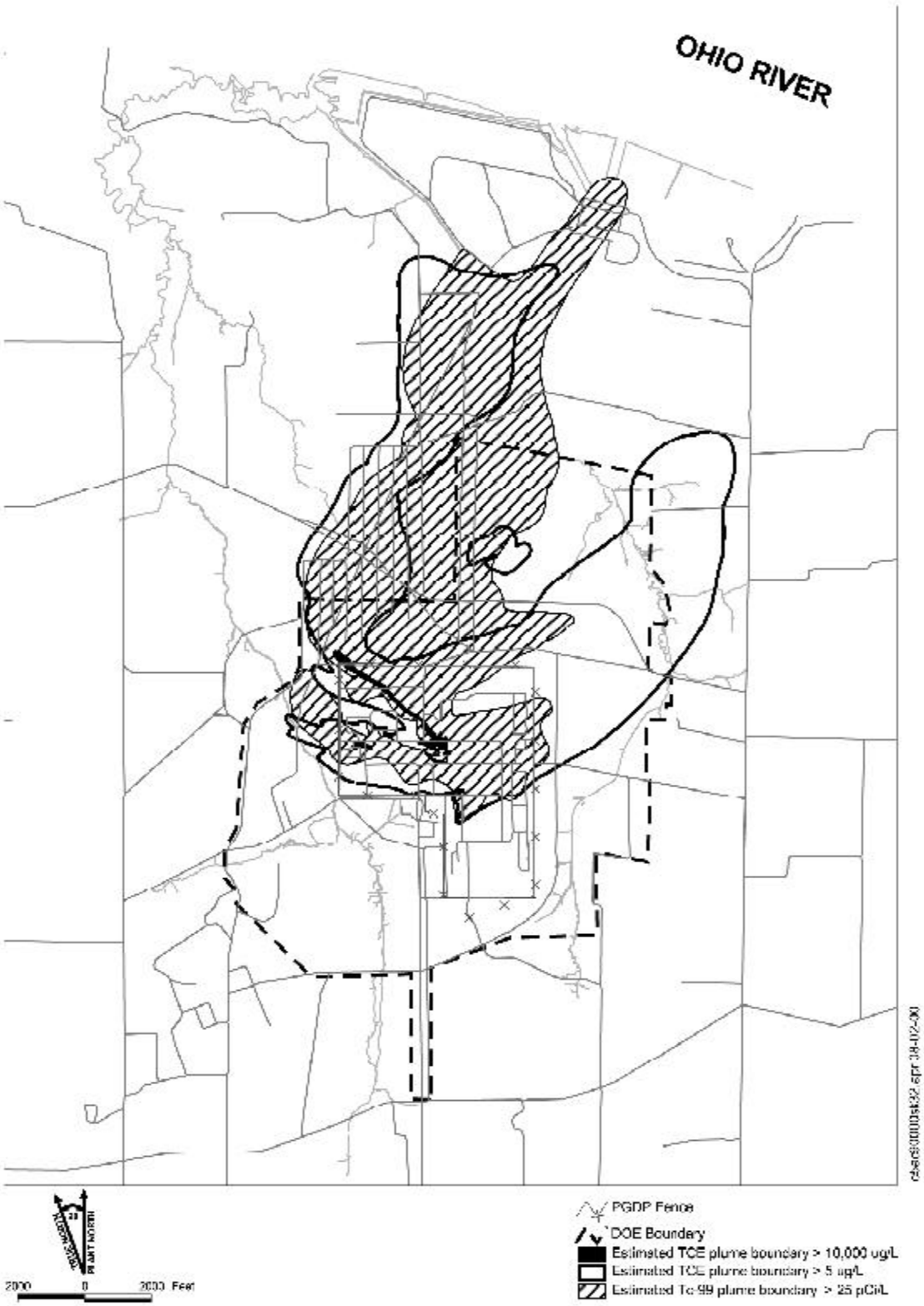

Figure 9.1 Off-site extension of groundwater plumes.

systems at Paducah. The pump-and-treat system installed northwest of the plant also controls the highest concentrations of dissolved ^{99}Tc that would otherwise migrate offsite. Continued groundwater monitoring serves to identify the extent of contamination, predict the possible fate of the contaminants, and determine the movement of groundwater near the plant. To date, three groundwater plumes have been identified emanating from the Paducah Site (Figure 9.1). Appendix D provides additional information about these plumes.

Groundwater monitoring at Paducah complies with one or more federal or state regulations and permit conditions and includes perimeter exitpathway monitoring and offsite water well monitoring. A more detailed description of groundwater monitoring is found in this Section under the heading of Groundwater Monitoring Program. Figures 9.2 and 9.3 show the locations of all wells sampled during 1999. Analytical results from the sampling described in this section are available upon request from the BJC Public Affairs Group.

Groundwater Hydrology

A portion of rainwater accumulates as groundwater by soaking into the ground, infiltrating porous soil and rock. The accumulation of groundwater in pore spaces of sediments creates a source of useable water - an aquifer (Figure 9.4). Water from the surface moving down through the soil makes its way by percolating downward through the pore spaces between soil grains (Figure 9.5). The smaller the pore spaces, the slower the flow of water through the sediment. The physical property that describes the ease with which water can move through the pore spaces and fractures in a material is called hydraulic conductivity, or permeability. Permeability is determined not only by the volume and size of the pore spaces but also by how well the pore spaces are connected. Aquifers are found in permeable sediments (such as sand and gravel) and rocks (such as sandstone and fractured limestone). Less permeable sediments (such as clay) and rocks (such as shale and dense limestone) make up aquitards that restrict groundwater movement. The boundary between the unsaturated and the saturated zones is known as the water table. This boundary usually, but not always, gently mirrors the surface topography, rising above natural exits such as springs, swamps, and beds of streams and rivers, where groundwater is discharged to the surface.

Groundwater movement is determined by differences in hydraulic head (a function of the energy associated with the water's elevation above sea level and the pressures exerted on it by surrounding water). Water will rise in a well casing in response to the pressure of the water surrounding the well's screened zone. The depth to water in the well is measured and the elevation calculated to determine the hydraulic head of the water in the monitored zone (Figure 9.6). The hydraulic gradient measures the difference in hydraulic head over a specified distance. By comparing the water levels in adjacent wells screened in the same zone, a horizontal hydraulic gradient can be determined and the lateral direction of groundwater flow can be predicted. Only wells screened in the same zones are considered when determining the horizontal gradient. Wells screened above and below an aquitard can also have different hydraulic heads, thus defining a vertical gradient. If the water levels in deeper wells are lower than those in shallower wells, the vertical component of flow is downward.

Permeability of the subsurface strata containing the aquifer also plays an essential role in the direction of groundwater flow through an aquifer system. Because the earth's sediments and their permeability vary greatly, groundwater flowing through subsurface strata does not travel at a constant rate or without impediment. As groundwater moves in the downgradient direction, it has both a horizontal and a vertical component, just as a household drain moves tap water both horizontally and vertically, seeking the lowest point of exit. Aquitards deflect groundwater movement as drainpipe walls control the direction of tap water movement. In an aquifer constrained by aquitards such as

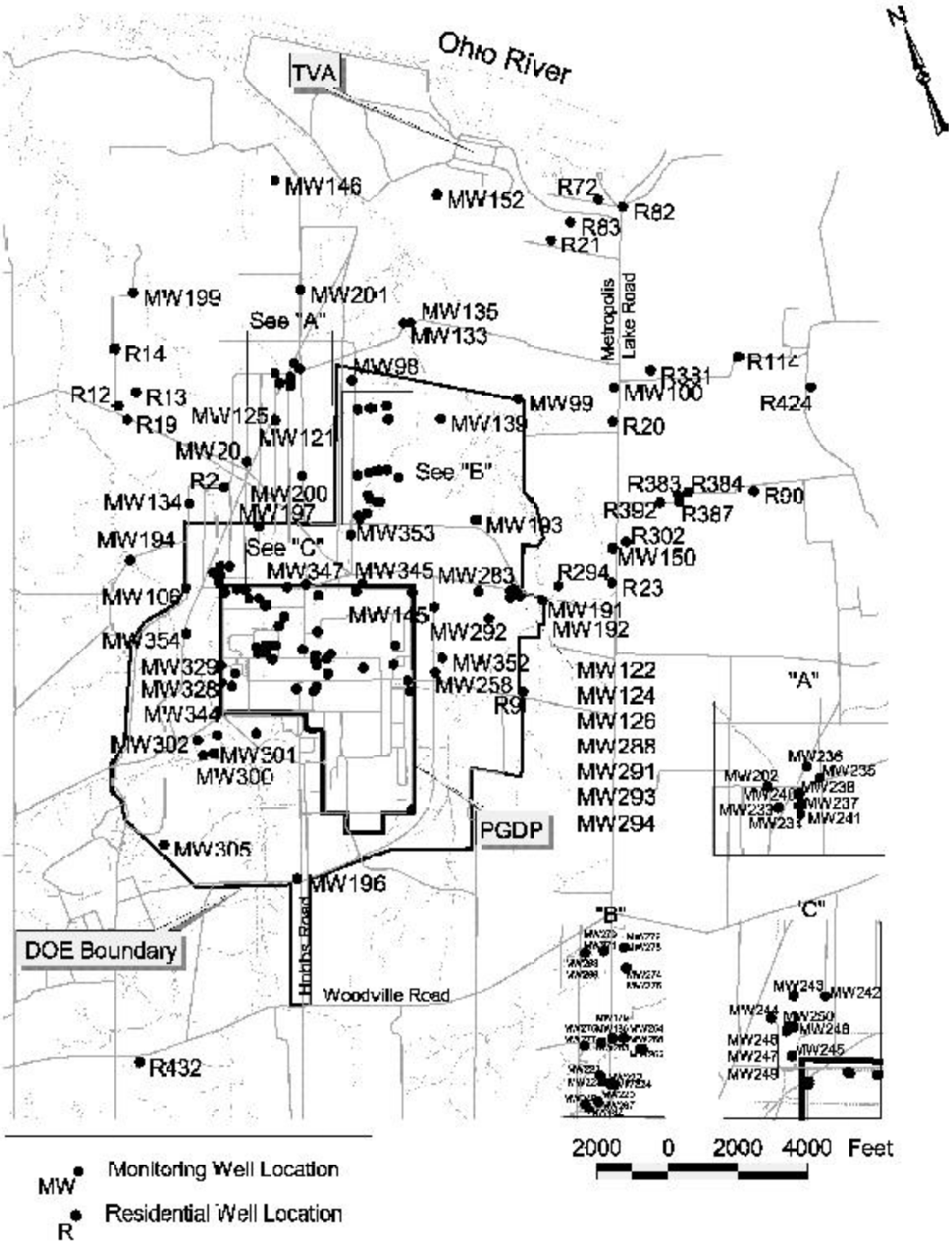

FIgure 9.2 Wells sampled in the vicinity of the Paducah Site.

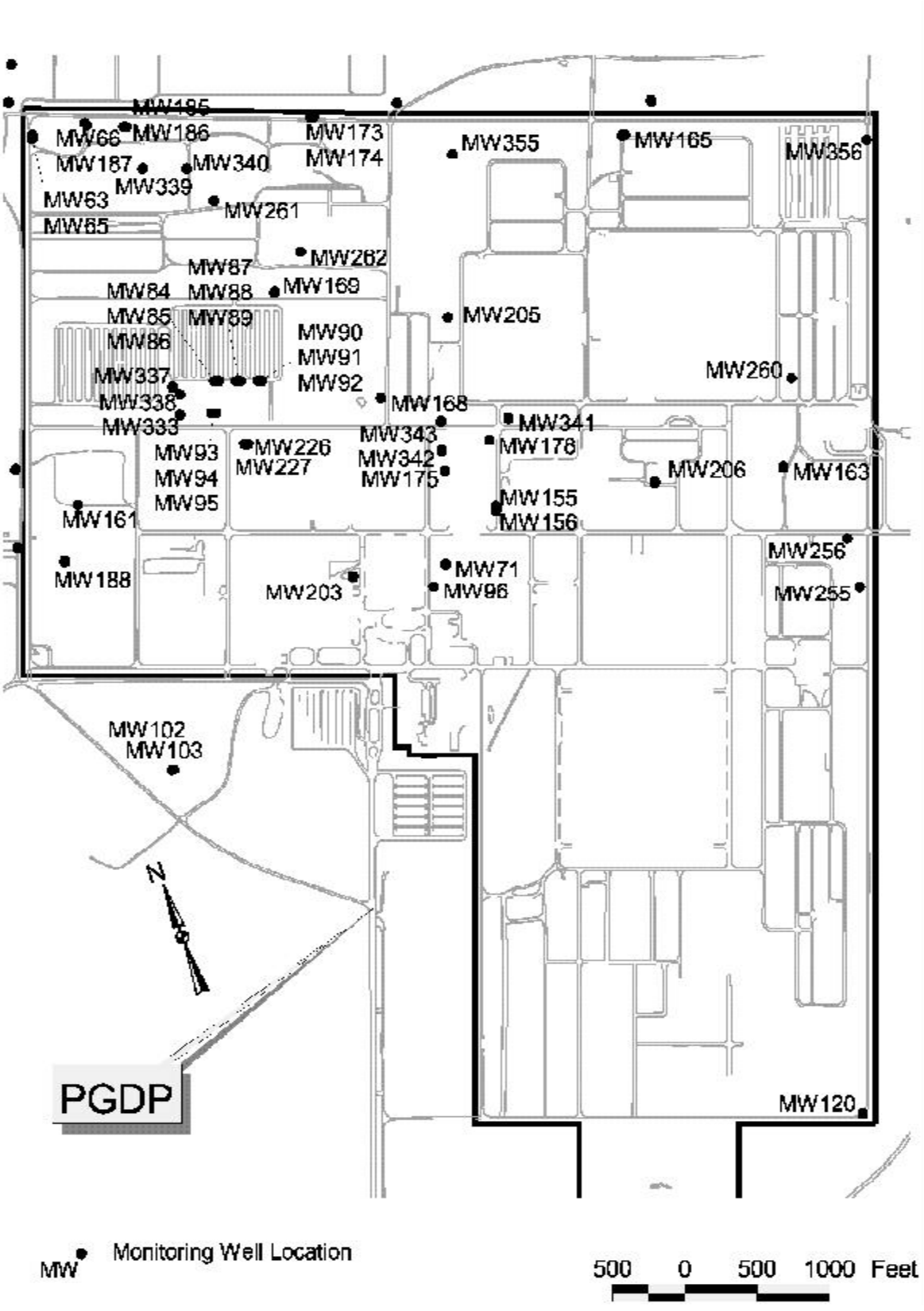

Figure 9.3 Wells sampled inside the perimeter fence.

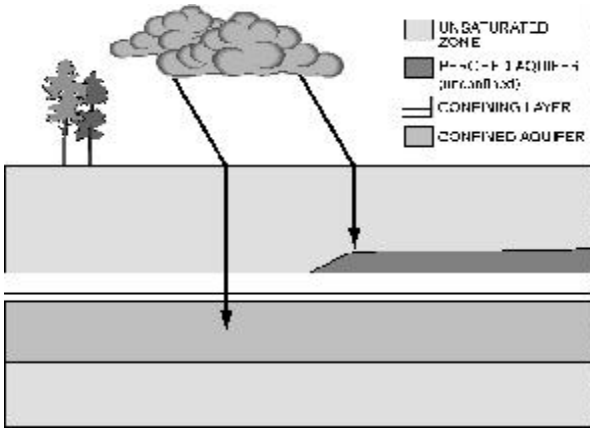

Figure 9.4 Typical path for rainwater accumulation as groundwater.

horizontal clay layers, the downgradient direction tends to be more horizontal than vertical.

Groundwater aquifers are one of the primary pathways by which potentially hazardous substances can spread through the environment. Substances placed in the soil may migrate downward due to gravity or be dissolved in rainwater, which moves them downward through the unsaturated zone into the aquifer. The contaminated water then flows downgradient toward the discharge point. Monitoring wells (MWs) are used extensively to assess the effect of plant operations on nearby groundwater quality. Wells positioned to sample groundwater flowing away from a site are called downgradient wells, and wells placed to sample groundwater before it flows under a site are called upgradient wells. Any contamination of the downgradient wells not present in the upgradient wells at a site may be assumed to be a product of that site. Wells can be drilled to various depths in the saturated zone and be screened to monitor the recharge area above the aquifer, different horizons within the aquifer, or water-bearing zones below the aquifer. Vertical and horizontal groundwater flow directions are determined by the permeability and continuity of geologic strata in addition to hydraulic head. To effectively monitor the movement of groundwater and any hazardous constituents it may contain, hydrogeologists at the Paducah Site have undertaken many detailed studies of the geology of strata beneath the site.

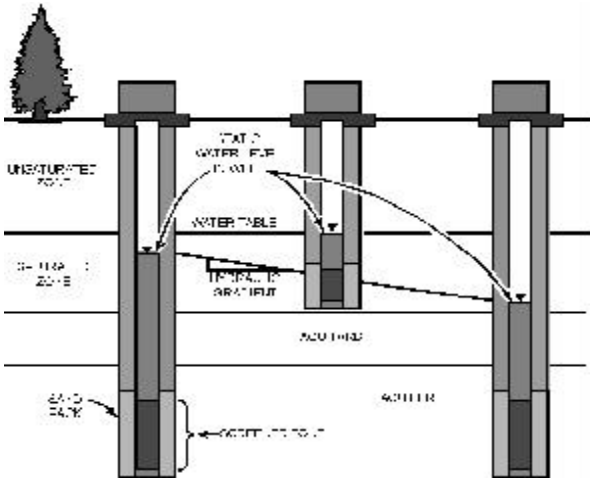

Figure 9.6 Monitoring well construction showing relationship between screened zone and water level in wells where limited flow in the aquifer is to the right.

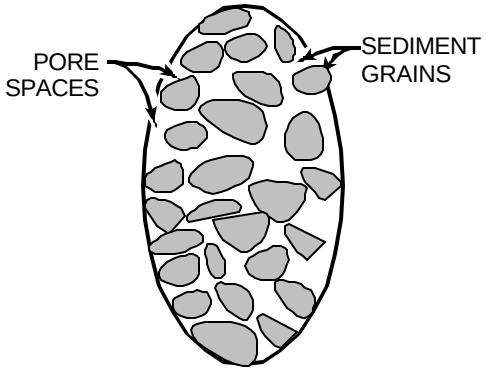

Figure 9.5 Pore spaces in soil.

Geologic and Hydrogeologic Setting

The Paducah Site, located in the Jackson Purchase region of western Kentucky, lies within the northern tip of the Mississippi Embayment portion of the Gulf Coastal Plain Province. The Mississippi Embayment is a large sedimentary trough oriented nearly north-south that received sediments during the Cretaceous and Tertiary geologic time periods. Figure 9.7 is a schematic cross-section illustrating regional stratigraphic relationships in the vicinity of the Paducah Site.

During the Cretaceous period, sediments deposited in a coastal marine environment formed the McNairy Formation. For the most part, the McNairy Formation is sandy at the bottom and silty at the top. A few exceptions to this are lenses of clay and at least one fairly continuous string of gravel.

Above the McNairy is the Clayton Formation. The Clayton was deposited during the early Paleocene geologic epoch in an environment so similar to that of the McNairy that the Clayton and upper portion of the McNairy are indistinguishable in lithologic samples. Later in the Paleocene, the Porters Creek Clay was deposited in marine and brackish water environments in a sea that occupied most of the Mississippi Embayment. These formations, the McNairy/Clayton and the Porters Creek Clay, dip 9 to 10.5 m (30 to 35 ft) per mile to the south-southwest.

The next feature in the geologic history at the Paducah Site is a Pleistocene-age river valley occupying approximately the same position as the present day Ohio and Tennessee river valleys. In forming the valley, braided stream channels of the ancestral Tennessee River, and possibly several "feeder" streams, eroded any sediments deposited after the Paleocene Porters Creek Clay and before the Pleistocene. The river system also eroded portions of the Porters Creek Clay and the McNairy/Clayton Formation and cut a prominent terrace in the Porters Creek Clay

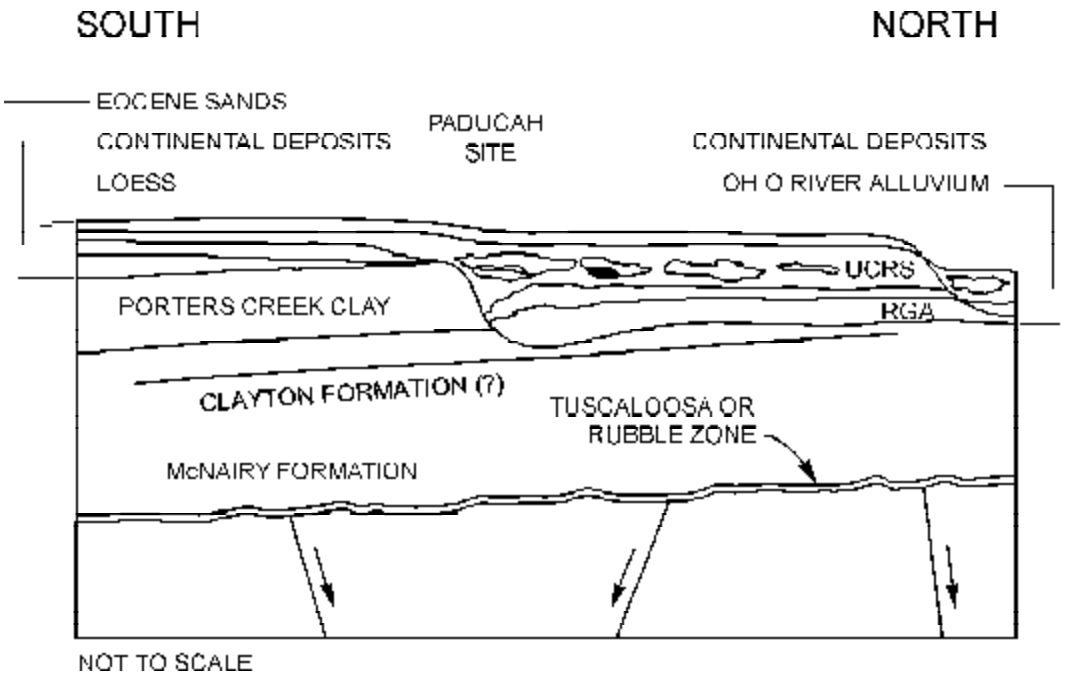

Figure 9.7 North-South section showing regional stratigraphic relationships.

at the south end of the plant. The sediments deposited on this erosional surface are termed continental deposits. The lower portion of the continental deposits consists of approximately 9 m (30 ft) of stream gravel and sand.

Over time, sediments from the retreating glaciers dammed the river valley, causing the formation of a lake. Silts and clays with thin zones of sand and occasional gravel were deposited in the lake, forming the upper portion of the continental deposits. These deposits range from approximately 1.5 to 17 m (5 to 55 ft) thick.

Finally, loess, a wind-blown silt, overlies the continental deposits throughout the site. Thickness of loess deposits varies from approximately 1.5 to 8 m (5 to 25 ft), averaging approximately 4.6 m (15 ft). The local groundwater flow system at the Paducah Site contains four major components: the McNairy flow system, the Regional Gravel Aquifer (RGA), the Upper Continental Recharge System (UCRS), and the terrace gravels.

- The McNairy flow system consists of interbedded and interlensing sand, silt, and clay of the McNairy Formation. Sand facies account for 40 to 50% of the total formation thickness of approximately 69 m (225 ft).

- The RGA consists of sand and gravel facies in the lower continental deposits, gravel and coarse sand portions in the upper McNairy that are directly adjacent to the lower continental deposits, coarse-grained sediments at the base of the upper continental deposits, and alluvium adjacent to the Ohio River. These deposits have an average thickness of 9 m (30 ft) and range up to 21 m (70 ft) along an axis that trends east-west through the site. The RGA is the uppermost and primary aquifer, formerly used by private residences north of the Paducah Site.

- The UCRS consists mainly of clayey silt with interbedded sand and gravel in the upper continental deposits. The system is so named because of its characteristic recharge to the RGA.

- The terrace gravels consist of shallow Pliocene gravel deposits in the southern portion of the plant site. These deposits usually lack sufficient thickness and saturation to constitute an aquifer but may be an important source of groundwater recharge to the RGA.

Groundwater flow originates south of the Paducah Site within Eocene sands and the terrace gravels. Groundwater within the terrace gravels either discharges to local streams or recharges the RGA, although the flow regime of the terrace gravels is not fully understood. Groundwater flow through the UCRS is ultimately downward, also recharging the RGA. From the plant site, groundwater flows generally northward in the RGA toward the Ohio River, the local base level for the system.

Uses of Groundwater in the Vicinity

The WKWMA and some lightly populated farmlands are in the immediate vicinity of the Paducah Site. Homes are sparsely located along rural roads in the vicinity of the site. Three communities lie within 3.2 kilometers (2 miles) of the plant: Magruder Village to the southwest and Grahamville and Heath to the east.

Both groundwater and surface water sources have been used for water supply to residents and industries in the plant area. Wells in the area are screened at depths ranging from 4.6 to 75 m (15 to 245 ft). The majority of these wells are believed to be screened in the RGA. The Paducah Site continues to provide municipal water to all residents within the area of

groundwater contamination from the site. These residents' out-of-service wells are being utilized by DOE for sampling as a result of written agreements. Residential wells that are no longer sampled have been capped and locked.

Groundwater Monitoring Program

The primary objectives of groundwater monitoring at the Paducah Site are to detect as early as possible any contamination resulting from past and present land disposal of wastes and to provide the basis for developing groundwater quality assessments if contamination is detected. Additional objectives outlined in DOE Order 5400.1, *General Environmental Protection Progra*m, require that groundwater monitoring at all DOE facilities "... determine and document the effects of operations on groundwater quality and quantity." The Order specifically requires groundwater monitoring to be conducted on-site and in the vicinity of DOE facilities to accomplish the following:

- obtain data to determine baseline conditions of groundwater quality and quantity;
- demonstrate compliance with, and implementation of, all applicable regulations and DOE orders;
- provide data to permit early detection of groundwater pollution or contamination;
- provide a reporting mechanism for detected groundwater pollution or contamination;
- identify existing and potential groundwater contamination sources and maintain surveillance of these sources; and
- provide data for making decisions about land disposal practices and the management and protection of groundwater resources.

These objectives are outlined in three documents relating to groundwater monitoring: *Paducah Gaseous Diffusion Plant Groundwater Protection Program Management Plan* (Miller 1997), *Groundwater Protection Plan* (Miller 1998), and the *Paducah Site Environmental Monitoring Plan* (BJC 1998). Scheduled sampling continues for more than 150 monitoring wells and residential wells in accordance with DOE orders and federal, state, and local requirements. Well sampling is included in several different monitoring programs, which are described below.

RCRA Permit Monitoring Programs

At present, the only hazardous waste facility at the Paducah Site that requires groundwater monitoring is the C-404 Landfill (Figure 9.8). The C-404 Low-Level Radioactive Waste Burial Ground was used until 1986 for the disposal of uranium-contaminated solid wastes when it was determined that of the wastes disposed there, gold dissolver precipitate was considered a hazardous waste under RCRA. The landfill was covered with a RCRA-compliant clay cap and was certified closed as a hazardous waste landfill in 1987. The landfill is now monitored under post-closure monitoring requirements. According to EPA Hazardous Waste Permit KY8-890-008-982, 14 wells (MWs 84–95, 226, and 227) monitor groundwater quality of the UCRS (four wells) and the underlying RGA (ten wells) during the required post-closure care on a semiannual basis.

During 1999, MWs at the C-404 Landfill were sampled and analyzed for total and dissolved arsenic, cadmium, chromium, lead, mercury, and selenium and TCE. Evaluation of the groundwater monitoring data collected at the

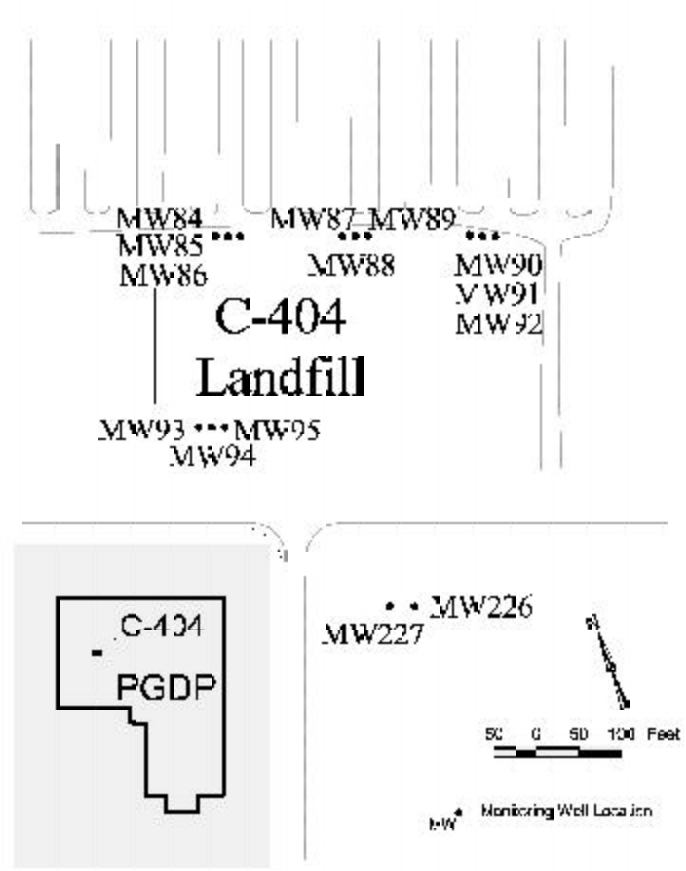

Figure 9.8 C-404 Landfill Monitoring wells.

C-404 Landfill includes immediate reporting to KDWM of results in RGA wells exceeding Kentucky maximum contaminant levels (401 KAR 47:030 Section 6) and statistical analysis of the RGA monitoring results. During 1999, TCE exceeded maximum contaminant levels in four upgradient RGA wells and one downgradient RGA well. Chromium also exceeded contaminant levels in one upgradient RGA well. KDWM was notified of the exceedences, as required by the permit. Results were reported to KDWM on a semi-annual basis. A summary of the maximum results for each of the wells is provided in Table 9.1.

In accordance with permit condition II.J.7.3.i, the Director of KDWM was notified May 10, 1996, in writing of a statistically significant increase of ^{99}Tc in MW 84. In 1998, statistical analyses of downgradient test well results compared with upgradient well results showed no significant increases for any analytes; therefore, KDWM removed the landfill from compliance (quarterly) monitoring back to detection (semiannual) monitoring. At this time, permit requirements for the sampling and analysis of ^{99}Tc and uranium were inadvertently omitted from the Paducah Site sampling program. The omission was discovered in 2000 and the analytes have been added back to the program. An NOV was issued to DOE by the state of Kentucky in 2000 for the omission.

State Solid Waste Disposal Regulations

Post-closure groundwater monitoring continues for the C-746-S Residential Landfill. The landfill stopped receiving solid waste before July 1, 1995, and was certified closed on October 31, 1995, by an independent engineering firm. The groundwater monitoring system for the C-746-S Residential Landfill also encompasses the C-746-T Inert Landfill which was certified closed in November 1992. The C-746-T Inert Landfill has fulfilled its two years of post-closure environmental monitoring and maintenance requirements and is awaiting final closure approval from KDWM.

The groundwater monitoring system for C-746-S and C-746-T consists of three upgradient and nine downgradient wells (Figure 9.9). The monitoring system is designed to monitor both the upper portions of the RGA (URGA) and lower portions of the RGA (LRGA). Upgradient wells are recognized as MW 181, MW 220, and MW 267 while downgradient wells are recognized as MW 179, MW 221 thru MW 225, and MW 263 thru MW 266. An additional well, MW 225, is monitored for static water level only. During 1999, MW 353 was installed as a new upgradient well because the proximity of MW 181, MW 220, and MW 267 to the landfill and apparent groundwater mounding within the aquifer created question of the true upgradient nature of the wells. MW 353 will be added to the

Table 9.1 Summary of Maximum Groundwater Results from the RGA at C-404.

	Upgradient Wells				Downgradient Wells					
Parameter	**MW 226**	**MW 227**	**MW 93**	**MW 95**	**MW 84**	**MW 86**	**MW 87**	**MW 89**	**MW 90**	**MW 92**
Arsenic* (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium* (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium* (mg/L)	0.125	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium, Dissolved* (mg/L)	ND	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead* (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury* (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium* (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TCE (ug/L)	42	8	7	8	9	2	ND	ND	2	ND

ND = not detected
NA = not analyzed
*Dissolved portion of metals concentrations analyzed only upon detection in the total portion.

monitoring system and the permit when eight quarters of sampling have been completed.

The MWs are sampled quarterly and in accordance with Kentucky Administrative Regulations (401 KAR 48:300). The analytes are dictated by a KDWM approved solid waste landfill permit modification. Evaluation of the groundwater monitoring data collected at the C-746-S and C-746-T landfills requires immediate reporting to KDWM of results exceeding Kentucky maximum contaminant levels (401 KAR 47:030 Section 6) and statistical analysis of the results for constituents that do not have a maximum contaminant level.

During 1999, TCE exceeded contaminant levels in three downgradient wells; chromium exceeded contaminant levels in two upgradient wells and six downgradient wells; and beta activity exceeded contaminant levels in one upgradient well and three downgradient wells. KDWM was notified of the exceedences, as required by the permit. Results were reported to KDWM on a quarterly basis. A summary of the maximum results for each of the wells is provided in Table 9.2.

A new solid waste landfill at the Paducah Site, identified as the C-746-U Contained Landfill, was completed in 1996 and operation was initiated in 1997. Solid waste regulations require groundwater characterization of the uppermost aquifer down to and including the clusters (Figure 9.8). Each cluster is made up of one well in the URGA and one well in the LRGA. One well cluster (MW 276, MW 277) is located upgradient of the facility and four wells downgradient.

Evaluation of the groundwater monitoring data collected at the C-746-U landfill included, for permitted wells, immediate reporting to KDWM of results exceeding Kentucky maximum contaminant levels (401 KAR 47:030 Section 6) and statistical analysis of the results for constituents that do not have a maximum contaminant level. During 1999, TCE exceeded contaminant levels in two upgradient wells; chromium exceeded contaminant levels in two

upgradient wells and seven downgradient wells; and beta activity exceeded contaminant levels in one upgradient well and six downgradient wells. KDWM was notified of the exceedances, as required by the permit. Results were reported to KDWM on a quarterly basis. A summary of the maximum results of each of the wells is provided in Table 9.3.

C-746-K Sanitary Landfill Groundwater Monitoring

The C-746-K Sanitary Landfill was used at PGDP between 1951 and 1981 primarily for the disposal of fly ash. Post-closure groundwater monitoring continues for the C-746-K Landfill on a quarterly basis. The UCRS and RGA are not present at the C-746-K site. Wells at the landfill

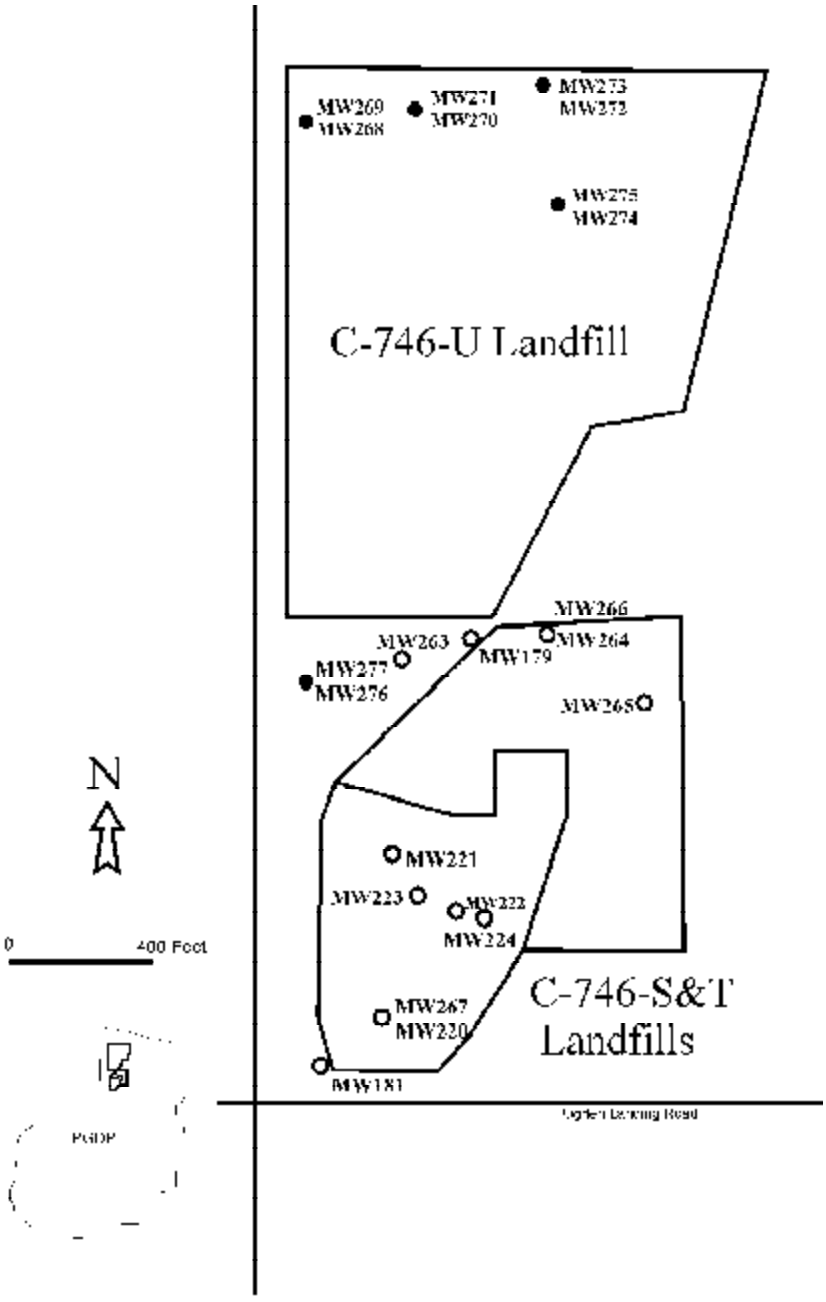

Figure 9.9 Monitoring well locations near the landfills.

Table 9.2 Summary of Maximum Groundwater Results for C-746-S&T

	Analysis	Upgradient Wells (MW###)				Downgradient Wells (MW###)								
		181	220	267	353	179	221	222	223	224	263	264	265	266
Metals (mg/L)	Barium	0.46	0.205	0.223	0.205	ND	0.248	0.3	0.215	0.236	0.065	0.185	0.231	0.05
	Barium, Dissolved	0.161	0.206	0.22	0.133	NA	0.245	0.298	0.21	0.234	0.065	0.183	0.229	0.05
	Chromium	1.16	ND	0.219	ND	ND	0.082	0.07	0.074	ND	0.36	ND	1.86	0.766
	Chromium, Dissolved	0.05	ND	0.05	ND	NA	0.05	0.05	0.05	ND	0.05	ND	0.05	0.05
	Cobalt	0.05	0.05	ND	0.014	ND	ND	0.05	ND	ND	ND	ND	ND	ND
	Iron	46.2	0.36	1.22	29.1	0.55	0.803	3.49	1.49	ND	1.2	0.67	10.9	5.74
	Nickel	0.653	1.05	0.1	0.07	ND	0.61	0.883	0.78	ND	ND	ND	0.144	ND
	Sodium	53.4	38.1	49.8	90.1	70.7	45.6	53.2	44.8	64.4	50.8	47.2	39.5	37.4
	Uranium	ND	ND	ND	0.003	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Uranium, Dissolved	NA	NA	NA	0.001	ND	NA	NA	NA	NA	ND	NA	NA	NA
	Other Metals[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rad (pCi/L)	Alpha activity	7.36	ND	ND	6.24	7.96	10.93	ND	ND	ND	ND	ND	ND	ND
	Beta activity	154.6	23.62	35.56	176.5	249.9	53.25	24.11	16.6	16.9	71.54	16.44	9.64	25.1
	Technetium-99	151.7	26.1	32.6	238	199	30.3	21	21.2	ND	58.9	18.2	ND	ND
VOC (ug/L)	Trichloroethene	1	ND	ND	ND	6	3	ND	ND	2	18	3	4	6
	Other VOCs[2]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Other	Chemical Oxygen Demand	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chloride (mg/L)	58.9	40.7	65.2	54.2	37.3	47.4	42.3	46.5	46.5	49.9	53.6	34.6	48.2
	Dissolved Solids (mg/L)	284	215	251	901	571	249	284	247	386	327	305	277	344
	Nitrate as Nitrogen (mg/L)	2	2.3	2.9	1.4	ND	1.7	1.7	2.3	1.7	1.6	ND	ND	1.2
	Total Organic Carbon (mg/L)	1.5	1.2	1.2	3.2	1.5	1.1	1.2	1	1.1	2	1.1	1.7	1
	Total Organic Halides (ug/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Turbidity (NTU)	700	5.1	4.1	750	4.9	3.5	34	49	0.5	5.9	6.5	75	32

ND = not detected
NA = not analyzed

[1] Other metals include: Antimony; Arsenic; Beryllium; Cadmium; Copper; Lead; Mercury; Selenium; Silver; Thallium; Vanadium; Zinc

[2] Other VOCs include: 1,1,1,2-Tetrachloroethane; 1,1,1-Trichloroethane; 1,1,2,2-Tetrachloroethane; 1,1,2-Trichloroethane; 1,1-Dichloroethane; 1,1-Dichloroethene; 1,2,3-Trichloropropane; 1,2-Dibromo-3-chloropropane; 1,2-Dibromoethane; 1,2-Dichlorobenzene; 1,2-Dichloroethane; 1,2-Dichloropropane; 1,4- ichlorobenzene; 2-Butanone; 2-Chloroethyl vinyl ether; 2-Hexanone; 4-Methyl-2-pentanone; Acetone; Acrolein; Acrylonitrile; Benzene; Bromochloromethane; Bromodichloromethane; Bromoform; Bromomethane; Carbon disulfide; Carbon tetrachloride; Chlorobenzene; Chloroethane; Chloroform; Chloromethane; cis-1,2-Dichloroethene; cis-1,3-Dichloropropene; Dibromochloromethane; Dibromomethane; Dichlorodifluoromethane; Dimethylbenzene; Ethanol; Ethyl methacrylate; Ethylbenzene; Iodomethane; Methylene chloride; Styrene; Tetrachloroethene; Toluene; trans-1,2-Dichloroethene; trans-1,3-Dichloropropene; Trans-1,4-Dichloro-2-butene; Trichlorofluoromethane; Vinyl acetate; and Vinyl chloride

Table 9.3 Summary of Maximum Groundwater Results at C-746-U

		Monitoring Wells (MW###)									
	Analysis	**276**	**277**	**268**	**269**	**270**	**271**	**272**	**273**	**274**	**275**
Metals	Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND
(mg/L)	Arsenic, dissolved	NA	NA	NA	NA	NA	NA	NA	NA	0.005	NA
	Barium	0.25	0.23	0.179	0.06	0.085	0.16	0.243	0.186	0.223	0.209
	Barium, dissolved	0.231	0.24	0.178	0.057	0.082	0.156	0.169	0.19	0.2	0.21
	Chromium	2.24	0.498	ND	0.81	2.86	0.57	0.094	0.13	3.37	0.61
	Chromium, dissolved	0.05	0.05	ND	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Copper	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND
	Iron	10.8	2.18	2.8	5.62	16	2.55	1.55	3.91	17.1	5.26
	Nickel	ND	0.11	ND	0.1	ND	ND	0.1	ND	0.1	0.17
	Sodium	37.3	33.3	34.6	52.6	45.3	42.6	55.3	39	43.2	39.5
	Other Metals[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rads	Alpha activity	3.45	4.56	ND	ND	3.24	5.54	3.93	3.28	4.19	10.94
(pCi/L)	Beta activity	105.0	30.37	36.84	116.3	37.13	51.33	81	124.6	165.9	286.6
	Technetium-99	85.1	19.6	38.9	113	32.6	55.2	99.6	128.8	156	258.6
VOC	Bromochloromethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	5
(ug/L)	Trichloroethene	19	24	ND	1	ND	ND	ND	ND	ND	ND
	Other VOCs[2]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Other	Chemical Oxygen Demand (mg/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Chloride (mg/L)	55.5	52.8	14.4	29.7	26.2	24.5	66.4	38	39.2	37.8
	Dissolved Solids (mg/L)	241	228	187	328	270	239	286	205	228	218
	Nitrate as Nitrogen (mg/L)	1.4	1.2	ND	ND	1.1	1.1	1.1	1.1	1.3	1.5
	Total Organic Carbon (mg/L)	1	1	1	1	1	1	1	1.1	1.2	1
	Total Organic Halides (ug/L)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Turbidity (NTU)	50	12	4.6	25	45	14	13	19	160	60

ND = not detected
NA = not analyzed

[1] Other metals include: Antimony; Beryllium; Cadmium; Cobalt; Lead; Mercury; Selenium; Silver; Thallium; Uranium; Vanadium; Zinc

[2] Other VOCs include: 1,1,1,2-Tetrachloroethane; 1,1,1-Trichloroethane; 1,1,2,2-Tetrachloroethane; 1,1,2-Trichloroethane; 1,1-Dichloroethane; 1,1-Dichloroethene; 1,2,3-Trichloropropane; 1,2-Dibromo-3-chloropropane; 1,2-Dibromoethane; 1,2-Dichlorobenzene; 1,2-Dichloroethane; 1,2-Dichloropropane; 1,4-Dichlorobenzene; 2-Butanone; 2-Chloroethyl vinyl ether; 2-Hexanone; 4-Methyl-2-pentanone; Acetone; Acrolein; Acrylonitrile; Benzene; Bromodichloromethane; Bromoform; Bromomethane; Carbon disulfide; Carbon tetrachloride; Chlorobenzene; Chloroethane; Chloroform; Chloromethane; cis-1,2-Dichloroethene; cis-1,3-Dichloropropene; Dibromochloromethane; Dibromomethane; Dichlorodifluoromethane; Dimethylbenzene; Ethanol; Ethyl methacrylate; Ethylbenzene; Iodomethane; Methylene chloride; Styrene; Tetrachloroethene; Toluene; trans-1,2-Dichloroethene; trans-1,3-Dichloropropene; Trans-1,4-Dichloro-2-butene; Trichlorofluoromethane; Vinyl acetate; and Vinyl chloride

are installed to monitor groundwater in the terrace gravels. A summary of the maximum results for each of the wells is provided in Table 9.4. Complete results of the monitoring were reported semi-annually in the FFA Semiannual Progress Report.

Federal Facility Agreement Monitoring

The FFA requires monthly sampling of residential wells potentially affected by the contaminant plume (DOE 1998). Currently, only three residential wells (R2, R294, and R302) meet this criterion. Eighteen other residential wells are monitored semiannually per the FFA. Additionally, MW 66 (located on site at the northwest corner of the plant) is required to be sampled on a monthly basis. All monthly sampled wells were analyzed for gross alpha and beta, TCE, and ^{99}Tc. MW 66 is sampled annually for uranium; it was not detected in 1999. As stated previously, the hydrologic unit in which residential wells are screened is uncertain; however, most are believed to be RGA wells. Table 9.5 provides a summary of the maximum detected results for the monthly monitoring programs. Semiannual residential sampling results yielded no detections of TCE and ^{99}Tc.

Two residential wells, R424 and R432, are also sampled semiannually. These wells contain TCE in the groundwater above the action limit of 1 µg/L, however, their location makes it highly improbable that the contaminants migrated from the Paducah Site. For these wells, DOE has provided the residents with a carbon filtering system to allow them to have safe drinking water. These filters are replaced semiannually and sampled before and after filter replacement. All residents were notified by mail of the results.

Additionally, DOE sampled the groundwater wells of 23 residents that requested special sampling of their wells during 1999. These residents were also notified by mail of the results.

Environmental Surveillance Monitoring

Environmental surveillance monitoring is defined as perimeter exit pathway monitoring and off-site water well monitoring. Environmental surveillance monitoring is conducted in support of DOE Orders and other laws and regulations as addressed in the *Paducah Gaseous Diffusion Plant Environmental Monitoring Plan* (BJC 1998). Specific wells monitored for environmental surveillance are as follows:

- *Annual Monitoring Program* - (*UCRS*) MWs 96, 180, 182, and 192; (*RGA*) MWs 71, 106, 134, 155, 156, 161, 163, 168, 169, 175, 178, 188, 191, 193, 200, 201, 203, 205, and 206; (*McNairy*) MW 133;

- *Annual Background Monitoring Program* - (*Terrace Gravels*) MW 196; (*Eocene Sand*) MW 305; (*RGA*) MWs 103, 150, 194, and 199; (*McNairy*) MWs 102, 120, 121, 122; and

- *Quarterly Monitoring Program* - (*UCRS*) MWs 166, 174, 186, and 187; (*RGA*) MWs 20, 63, 65, 98, 99, 100, 125, 135, 139, 146, 152, 165, 173, 185, 197, 202, 260, 261, 262, 328, 329, 333, 337, 338, 339, 340, 341, 342, 343, 345, 346, 347, 352, 353, 354, and 355; (*McNairy*) MW 356; (*Rubble Zone*) MWs 345, 346, and 347.

During 1999, surveillance wells were sampled for VOCs, gross alpha and beta activity, and ^{99}Tc. One well, MW 352, was unable to be sampled under the routine program due to a high solids content. Special sampling indicates that MW 352 was not adequately developed to allow proper sampling. Table 9.6 provides a summary of the maximum detected results for each hydrogeologic unit sampled for the surveillance program. The maximum TCE value reported in the RGA is 220,000 µg/L from MW 156. MW 156 is located at the southeast corner of C-400.

Table 9.4 Summary of Maximum Groundwater Results at C-746-K

	Analysis	MW 300	MW 301	MW 302	MW 344
Metals	Aluminum	27	ND	0.22	9.26
(mg/L)	Arsenic	ND	ND	ND	0.006
	Arsenic, dissolved	NA	NA	NA	0.006
	Barium	ND	0.099	0.228	0.131
	Barium, dissolved	NA	0.051	0.081	0.08
	Cadmium	ND	ND	ND	ND
	Iron	559	203	ND	16.1
	Lead	ND	ND	ND	ND
	Magnesium	137	47.7	26.4	25.2
	Manganese	28.3	18.2	0.157	0.871
	Nickel	0.29	0.05	ND	ND
	Potassium	18.1	22.2	ND	2.36
	Sodium	36	26.3	102	36.5
	Strontium	1.78	1.03	0.4	0.33
	Uranium	0.005	0.005	ND	ND
	Uranium, dissolved	0.005	0.004	NA	NA
Rads	Alpha activity	ND	17.2	ND	5.38
(pCi/L)	Beta activity	ND	41.56	ND	14.19
	^{99}Tc	ND	ND	ND	ND
VOCs	1,1-Dichloroethene	250	ND	ND	ND
(µg/L)	1,1-Dichloroethane	110	ND	ND	ND
	cis-1,2-Dichloroethene	2300	18	ND	ND
	Trichloroethene	120	ND	ND	ND
	Other VOCs[1]	ND	ND	ND	ND
Other	Chromium, hexavalent	ND	ND	ND	ND
(mg/L)	Silica	44	19	41	16
	Suspended Solids	35	106	ND	213

ND = not detected
NA = not analyzed

[1] Other VOCs include: 1,1,1-Trichloroethane; 1,1,2-Trichloroethane; 1,2-Dichloroethane; Benzene; Bromodichloromethane; Carbon tetrachloride; Chloroform; Dimethylbenzene; Ethylbenzene; Tetrachloroethene; Toluene; trans-1,2-Dichloroethene; and Vinyl chloride

This level of TCE is consistent with levels shown at this well in the past. TCE was also detected in the McNairy at 160 µg/L in MW 356. MW 356 was first sampled in December 1999. Only one other well completed in the McNairy (MW 133) showed any TCE detections (1 µg/L).

Three wells, MWs 345, 346, and 347, have been installed penetrating the Rubble Zone, the formation underlying the McNairy. Initial sampling of the wells indicated no contamination.

Table 9.5 Summary of Maximum Groundwater Results from FFA Monthly Monitoring

Well Number	Alpha activity pCi/L	Beta activity pCi/L	^{99}Tc pCi/L	TCE ug/L
R2	4.55	1163.35	1309.5	2800
R294	ND	60.96	22.8	ND
R302	3.76	24.78	ND	ND
MW 66	3.42	1933.3	2662.6	11,000

ND = not detected

Environmental Restoration Activities

Northwest Plume Monitoring

The EPA approved an IRA ROD to hydraulically contain off-site migration of the northwest plume. This action was a first phase of remedial action for groundwater at the Paducah Site. Two extraction wells near a source of the northwest plume and two additional extraction wells farther north, near the centroid of the plume, were installed. Each set of extraction wells is surrounded by a monitoring well network. The network is used for monitoring groundwater quality and water levels to

Table 9.6 Summary of Maximum Groundwater Results from Environmental Surveillance Quarterly, Annual, and Background Monitoring

	Parameter	Eocene	Terrace Gravels	UCRS	RGA	McNairy	Rubble Zone
VOCs	1,1-Dichloroethane	ND	ND	ND	9	ND	ND
(µg/L)	1,1-Dichloroethene	ND	ND	ND	200	ND	ND
	Carbon tetrachloride	ND	ND	ND	220	ND	ND
	cis-1,2-Dichloroethene	ND	ND	710	ND	ND	ND
	Dimethylbenzene	ND	ND	19	ND	ND	ND
	Ethylbenzene	ND	ND	23	ND	ND	ND
	Toluene	ND	ND	ND	200	ND	ND
	Trichloroethene	ND	ND	750	220000	160	ND
	Vinyl chloride	ND	ND	1400	ND	ND	ND
	Other VOCs[1]	ND	ND	ND	ND	ND	ND
Rads	Uranium (mg/L)	0.003	0.001	0.21	0.006	0.008	0.001
	Alpha activity (pCi/L)	ND	ND	92.25	20.94	15.06	4.78
	Beta activity (pCi/L)	ND	ND	249.53	11271.1	150.94	8.83
	^{99}Tc (pCi/L)	ND	ND	78.48	14300	8.39	ND

ND = not detected

[1] Other VOCs include: 1,1,1-Trichloroethane; 1,1,2,2-Tetrachloroethane; 1,1,2-Trichloroethane; 1,2-Dichloroethane; 1,2-Dichloropropane; 1,2-Dimethylbenzene; 2-Butanone; 2-Hexanone; 4-Methyl-2-pentanone; Benzene; Bromodichloromethane; Bromoform; Carbon disulfide; Chlorobenzene; Chloroethane; Chloroform; Chloromethane; cis-1,3-Dichloropropene; Dibromochloromethane; m,p-Xylene; Methylene chloride; Styrene; Tetrachloroethene; trans-1,2-Dichloroethene; and trans-1,3-Dichloropropene

determine the effectiveness of the interim action. Collectively, the system is known as the Northwest Plume Groundwater System.

Long-term monitoring has been conducted at the Northwest Plume. Data gathered from 1995 through 1999 suggest that the overall concentration of TCE and ^{99}Tc in the majority of the wells is decreasing. This indicates that the well fields are beginning to achieve containment of the core of the plume. Other analytical data is also gathered to monitor the extraction system performance. A more detailed description of TCE and ^{99}Tc in the Northwest Plume is included in Appendix D. Summaries of the program's monitoring results are listed in Tables 9.7 and 9.8. The data for this program is reported semiannually in the FFA Semiannual Progress Report.

Northeast Plume Monitoring

A ROD was approved by the EPA in June of 1995. Implementation of the ROD was completed in 1996 and consisted of construction of two extraction wells, several monitoring wells and piezometers, and facilities required to transfer the TCE-contaminated water to the C-637 Cooling Tower for treatment. Groundwater quality and water level information obtained from the piezometers and monitoring wells are used to evaluate the effectiveness of the remedial action. The upgradient monitoring wells are used to detect possible ^{99}Tc contamination within the high concentration area of the plume before it reaches the extraction wells.

Monitoring results from the Northeast Plume indicate TCE levels have dropped significantly since implementation of the remedial action (BJC/PAD-169). Other analytical data is also gathered to monitor the extraction system performance. A more detailed description of TCE and ^{99}Tc in the Northeast Plume are included in Appendix D. A summary of the program's monitoring results is listed in Table 9.9. The data for this program is reported semiannually in the FFA Semiannual Progress Report.

Groundwater Monitoring Results

The primary objectives of groundwater monitoring at the Paducah Site are being met by the monitoring program. Contamination has been detected in groundwater off-site. Through the monitoring program, in conjunction with RIs, a footprint of the groundwater contamination has been mapped and is regularly updated. The program continues to expand each year to further delineate the boundaries of the footprint over time and to identify source locations for contaminants. Monitoring wells upgradient and downgradient from individual underground waste disposal facilities are sampled and analyzed for COCs. Contaminants identified by the monitoring program are evaluated both by technical assessment and statistically analyzed to determine if the source of the contaminants could be the disposal site being monitored. ^{99}Tc, beta activity and trichloroethene are found in the off-site and on-site contamination plumes. Chromium and dissolved solids are also present in some wells, although these contaminants are thought to be natural in origin and not a result of past practices. Groundwater monitoring results from all sampling efforts conducted by the Paducah Site are compiled in the Paducah Oak Ridge Environmental Information System (OREIS) database. A complete listing of analytical results is available upon request from the BJC Public Affairs Department.

Appendix D contains a more detailed interpretation of the TCE and ^{99}Tc groundwater contamination and plumes within the RGA. Detailed plume figures included in *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 1999 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2000b) have been omitted from this report due to space limitations. However, Figure 9.1 provides a summary of these figures.

Table 9.7 Summary of Maximum Groundwater Results from the Northwest Plume North Field Groundwater Monitoring

Parameter		MW 233	MW 234	MW 235	MW 236	MW 237	MW 238	MW 239	MW 240	MW 241
Metals (mg/L)	Aluminum	ND	ND	ND	ND	2.96	ND	ND	ND	ND
	Barium	0.124	0.157	0.158	0.153	0.322	0.134	ND	0.128	0.13
	Calcium	20.2	25.1	24.6	23.6	20.4	23.4	4.83	20.6	21.3
	Chromium	ND	0.385	0.127	0.11	ND	ND	ND	ND	ND
	Cobalt	ND	ND	ND	ND	ND	ND	0.013	ND	ND
	Iron	ND	2.4	1.7	2.71	2.08	ND	23.1	0.35	0.723
	Magnesium	7.87	9.71	9.85	9.56	7.78	9.06	2.98	8.44	8.38
	Manganese	ND	ND	ND	ND	ND	ND	0.823	ND	ND
	Nickel	ND	0.082	ND	ND	ND	ND	ND	ND	ND
	Potassium	ND	ND	ND	ND	ND	ND	7.93	ND	ND
	Sodium	29.9	34.6	37.4	35.8	75.2	31	19.8	29.3	29.1
	Other metals[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rad (pCi/L)	Alpha activity	ND	3.47	ND	ND	ND	ND	5.1	ND	ND
	Beta activity	45.97	663.27	595.07	729.45	10.16	374.24	24.52	328.47	235.4
	^{99}Tc	49.2	904	597	816	21.3	429.29	ND	409	238
VOCs (µg/L)	Benzene	50	ND	ND	ND	ND	ND	ND	ND	ND
	TCE	95	1800	1300	1500	ND	650	ND	760	450
	Other VOCs[2]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Other (mg/L)	Dissolved Solids	171	195	212	200	293	178	148	187	176
	Chloride	24.7	36.7	41	34	9.1	29.1	22.8	28.4	25.4
	Fluoride	0.16	0.14	0.15	0.16	0.55	0.17	0.32	0.16	0.15
	Nitrate as Nitrogen	1.8	2.3	2.3	2.5	1	2.4	ND	2.3	2
	Sulfate	13.8	19.1	18.9	20.7	31.4	19.6	18.3	18.9	19.4
	Alkalinity	84	85	87	88	173	84	52	81	83
	Phosphate as Phosphorous	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Silica	17	16	17	19	41	19	46	18	18
	Total Organic Carbon	ND	ND	ND	1	1.6	1	ND	ND	ND
	Total Phosphate as Phosphorus	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Turbidity (NTU)	1.6	32	16	29	50	1.2	36	3.6	8

ND = not detected

1 Other metals include: Antimony, Arsenic, Beryllium, Cadmium, Copper, Lead, Mercury, Molybdenum, Selenium, Silver, and Zinc

2 Other VOCs include: 1,1,1-Trichloroethane; 1,1,2-Trichloroethane; 1,1-Dichloroethane; 1,1-Dichloroethene; 1,2-Dichloroethane; Bromodichloromethane; Carbon tetrachloride; Chloroform; cis-1,2-Dichloroethene; Dimethylbenzene; Ethylbenzene; Tetrachloroethene; Toluene; trans-1,2-Dichloroethene; and Vinyl chloride

Table 9.8 Summary of Maximum Groundwater Results from the Northwest Plume South Field Groundwater Monitoring

	Parameter	MW 242	MW 243	MW 244	MW 245	MW 246	MW 247	MW 248	MW 249	MW 250
Metals	Aluminum	ND	ND	ND	11.8	ND	ND	ND	ND	ND
(mg/L)	Barium	0.268	0.177	0.098	0.177	ND	0.167	0.143	0.09	0.078
	Calcium	31.8	31.6	21.4	22.2	40.2	23.8	28.8	21.7	21.3
	Chromium	0.261	1.15	ND	ND	ND	ND	ND	ND	ND
	Cobalt	0.014	ND	ND	ND	ND	ND	ND	ND	ND
	Iron	3.65	6.9	0.226	10.4	0.25	6.99	0.219	0.472	0.27
	Magnesium	12.2	12.5	8.86	9.25	16.8	11.6	11.8	8.49	8.71
	Manganese	0.156	ND	ND	1.94	ND	0.86	ND	ND	ND
	Nickel	0.838	0.39	ND	ND	ND	ND	ND	ND	ND
	Potassium	ND	ND	ND	ND	ND	5.81	ND	ND	ND
	Sodium	27.7	30.8	30.4	28.1	110	37.6	27.8	34.5	32
	Other Metals[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rads	Alpha activity	ND	5.41	ND	ND	ND	ND	6.92	ND	4.08
(pCi/L)	Beta activity	118.39	953.58	23.28	74.7	ND	14.19	1503.64	54.44	75.52
	Neptunium-237	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Plutonium-239/240	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Radium	0.56	ND	ND	ND	ND	0.94	0.6	ND	ND
	Radon	104	156	137	189	397	118	225	157	137
	Technetium-99	130	1060	24.3	62.3	ND	ND	1550	41.8	680
	Thorium-230	ND	ND	ND	ND	ND	ND	ND	ND	ND
VOCs	TCE	180	3300	20	100	1	ND	9100	190	72
(µg/L)	Other VOCs[2]	ND	ND	ND	ND	ND	ND	ND	ND	ND
Others	Chloride	67.8	69.9	22.3	10.5	5.9	5.5	56.5	16.4	20.3
(mg/L)	Fluoride	ND	0.1	0.14	0.19	0.27	0.15	0.1	0.12	0.15
	Nitrate as Nitrogen	1.4	1.7	ND	ND	ND	ND	4.5	ND	ND
	Dissolved Solids	225	222	167	177	489	188	212	120	146
	Sulfate	10.9	11.2	11.3	11	206	ND	10	9.4	10.4
	Alkalinity	82	72	90	90	155	175	71	69	85
	Phosphate as Phosphorous	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Silica	18	16	18	28	37	5	18	18	18
	Total Organic Carbon	1.1	1	ND	ND	1.7	ND	ND	ND	ND
	Total Phosphate as Phosphorus	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Turbidity (NTU)	35	40	3.1	220	7.4	55	4.5	10	3.4

ND = not detected

[1] Other metals include: Antimony, Arsenic, Beryllium, Cadmium, Copper, Lead, Mercury, Molybdenum, Selenium, Silver, Uranium, and Zinc

[2] Other VOCs include: 1,1,1-Trichloroethane; 1,1,2-Trichloroethane; 1,1-Dichloroethane; 1,1-Dichloroethene; 1,2-Dichloroethane; Benzene; Bromodichloromethane; Carbon tetrachloride; Chloroform; cis-1,2-Dichloroethene; Dimethylbenzene; Ethylbenzene; Tetrachloroethene; Toluene; trans-1,2-Dichloroethene; and Vinyl chloride

Table 9.9 Summary of Maximum Groundwater Results from the Northeast Plume Groundwater Monitoring.

		Monitoring Well (MW ###)												
	Parameter	**124**	**126**	**145**	**255**	**256**	**258**	**283**	**284**	**288**	**291**	**292**	**293**	**294**
Metals (mg/L)	Aluminum	ND	ND	ND	0.363	ND	ND	ND	ND	ND	0.398	ND	ND	ND
	Barium	0.226	0.189	0.095	0.194	0.282	0.206	0.246	0.24	0.252	0.238	0.241	0.209	0.245
	Calcium	24.2	20.6	51.7	31.6	28.1	28.4	23.4	23.2	28.8	22.4	29.6	23.8	26
	Chromium	0.094	0.187	ND	0.419	ND	0.536	0.186	0.315	0.139	0.405	0.361	0.413	0.145
	Iron	0.954	3.58	ND	2.59	ND	7.75	0.914	2.94	1.06	1.85	4.54	3.19	1.16
	Magnesium	9.26	7.71	20.4	12.2	10.7	10.9	9.25	9.18	11.3	8.69	11.8	9.49	10.4
	Manganese	ND	ND	ND	0.226	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Nickel	ND	0.074	ND	0.195	ND	0.133	ND	ND	ND	ND	0.337	0.252	0.297
	Potassium	ND	ND	5.01	2.32	ND	2.18	ND	ND	ND	ND	ND	ND	ND
	Selenium	0.005	ND	ND	0.005	ND	0.005	ND	ND	ND	ND	ND	ND	ND
	Sodium	44.3	45.1	61.8	82.9	58.7	67.4	35.3	35.5	47.1	38.8	52.2	41.4	41.5
	Uranium	ND	ND	ND	ND	ND	0.001	ND	ND	ND	ND	ND	ND	ND
	Other Metals[1]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Rad (pCi/L)	Alpha activity	3.5	ND	ND	ND	ND	ND	ND	ND	3.71	ND	4.71	4.15	ND
	Beta activity	52.22	94.84	84.78	76.33	185.6	70.1	36.23	54.23	51.13	44.96	44.16	22.03	13.34
	Technetium-99	ND	ND	ND	ND	85	ND	25.43	ND	24.82	ND	24.2	ND	ND
VOC (ug/L)	Methylene chloride	NA	NA	NA	NA	NA	NA	580	NA	NA	NA	NA	NA	NA
	TCE	140	70	120	900	360	1300	250	310	860	280	1200	1300	1500
	Other VOCs[2]	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Other (mg/L)	Chloride	62.1	47.6	113	76	58	73	62.3	62.7	79	60.6	77	66.5	74
	Fluoride	0.16	0.19	0.17	0.21	0.18	0.19	0.12	0.12	0.13	0.12	0.15	0.13	0.12
	Nitrate as Nitrogen	1.7	1.2	ND	1.2	ND	1.7	1.3	1.4	1.7	1.5	1.6	1.7	1.7
	Sulfate	13.2	10.1	75.8	33.6	19.5	19.6	5.8	5.3	10.8	ND	9.5	8.3	6.8
	Dissolved Solids	226	220	436	357	281	302	209	209	261	204	271	224	228
	Alkalinity	88	100	130	164	134	136	79	77	99	79	109	84	82
	Phosphate as Phosphorous	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Silica	15	17	14	13	13	15	14	14	13	14	13	16	13
	Total Organic Carbon (TOC)	1.2	1	1.5	1.6	1.4	1.4	1.1	1.1	1.2	1	1.2	1.2	1
	Turbidity (NTU)	6	28	0.55	24	0.95	55	3.2	27	5.8	21	50	13	12

ND = not detected

1 Other metals include: Antimony, Arsenic, Beryllium, Cadmium, Cobalt, Copper, Lead, Mercury, Molybdenum, Silver, and Zinc

2 Other VOCs include: 1,1,1-Trichloroethane; 1,1,2-Trichloroethane; 1,1-Dichloroethane; 1,1-Dichloroethene; 1,2-Dichloroethane; Benzene; Bromodichloromethane; Carbon tetrachloride; Chloroform; cis-1,2-Dichloroethene; Dimethylbenzene; Ethylbenzene; Tetrachloroethene; Toluene; trans-1,2-Dichloroethene; and Vinyl chloride

The complete report is available from the DOE Environmental Information Center.

10 Special Investigations

Abstract

The Paducah Site often conducts investigations of various media that are not part of the routine environmental monitoring program. Relevant results are reported in the ASER. In 1999, the Paducah DOE Site Office participated with DOE Headquarters and U.S. Department of Justice (DOJ) officials in various environmental sampling activities. The data collected are relevant to environmental monitoring and environmental restoration program activities reported elsewhere in this document.

DOE/DOJ Investigation

Beginning in August 1999, the Paducah DOE Site Office participated with DOE Headquarters and U.S. Department of Justice (DOJ) officials in various environmental sampling activities conducted to assist investigators in determining appropriate actions as a result of recent lawsuits concerning the Paducah Site. This effort was ongoing through the end of 1999 with a limited amount of sampling in January 2000 (Figure 10.1).

Although data collected by DOE Headquarters and DOJ will not be provided due to issues associated with pending lawsuits, data collected during the investigation activities by the Paducah DOE Site Office are available for integration with other data from current remediation activities. During these investigations the Paducah DOE Site Office collected split samples resulting in 41 sediment samples, two sludge samples, 26 soil samples, 16 groundwater samples, 12 surface water samples, and two waste water samples. These

Figure 10.1 Soil sample collected during a special DOJ sampling activity.

samples were collected from locations within and around PGDP. The data obtained are presented in Appendix C of this report. Figures 10.2 and 10.3 show the locations and media sampled.

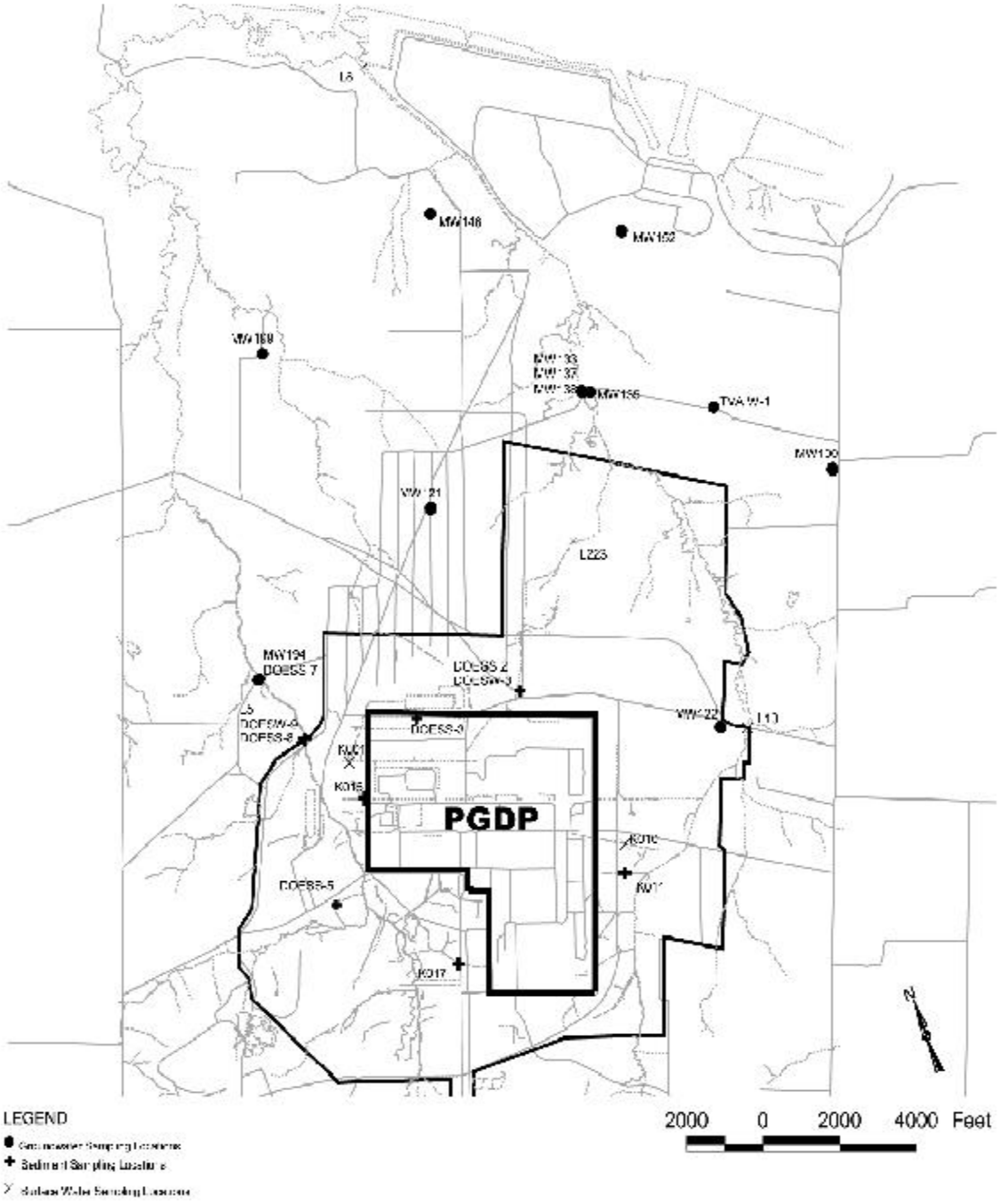

Figure 10.2 DOE special investigation sample locations.

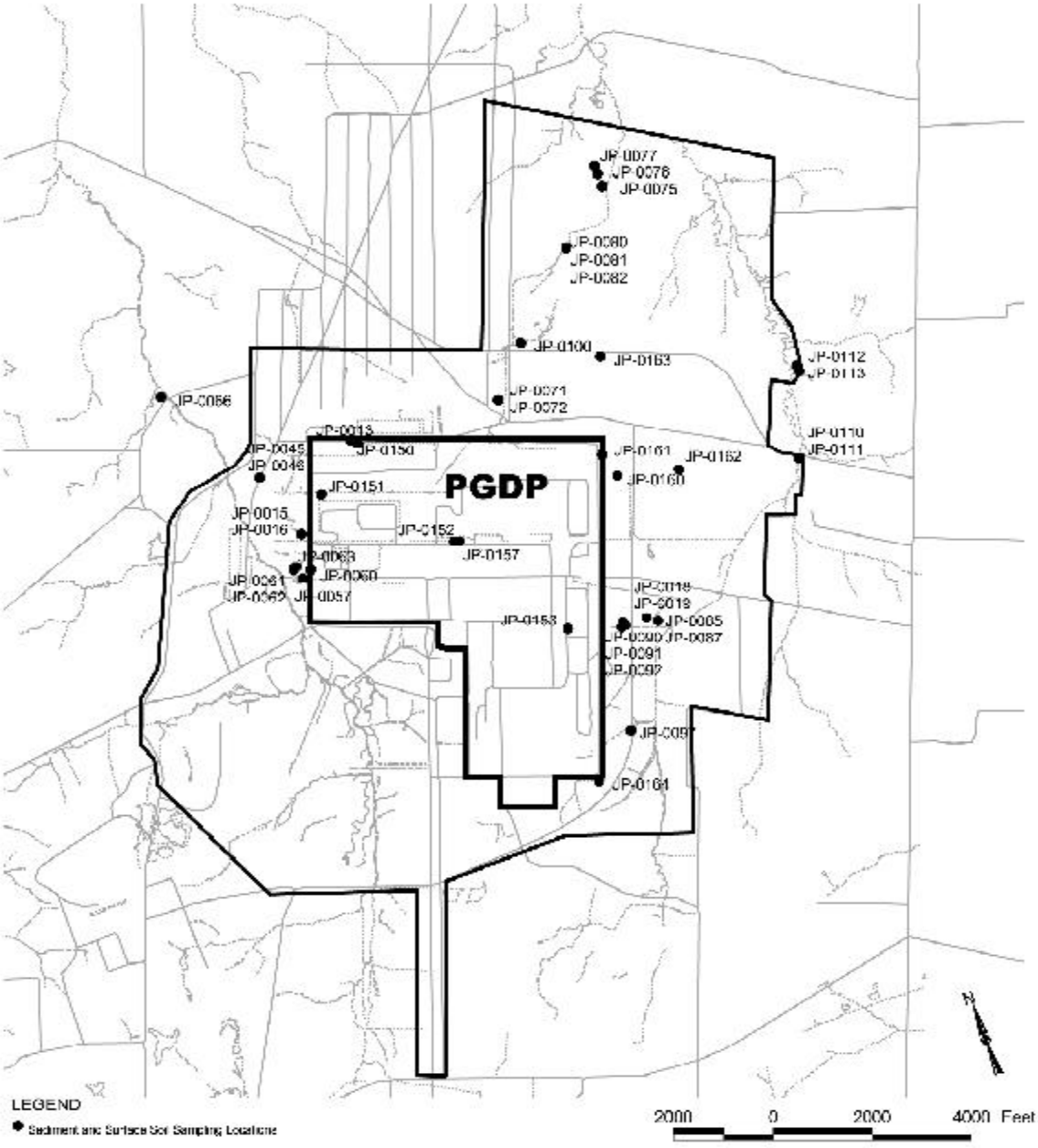

Figure 10.3 DOJ special investigation sample locations.

11 Quality Assurance

Abstract

The Paducah Site maintains a quality assurance/quality control (QA/QC) program to verify the integrity of data generated within the environmental monitoring program. Monitoring and sampling organizations at Paducah select sampling methods, instruments, locations, schedules, and other sampling and monitoring criteria based on applicable guidelines from various established authorities and by participation from compliance and analytical organizations at the site.

Introduction

The Paducah Site maintains a QA/QC program to verify the integrity of data generated within the environmental monitoring program. Each aspect of the monitoring program, from sample collection to data reporting, must address quality requirements and assessment standards. Requirements and guidelines for the QA/QC program at the Paducah Site are established by DOE Order 414.1, *Quality Assurance*; state and federal regulations; and documentation from EPA, the American National Standards Institute, the American Society of Mechanical Engineers, American Society of Testing and Materials (ASTM), and the American Society for Quality Control. The QA/QC program specifies organizational and programmatic elements to control equipment, design, documents, data, nonconformances, and records. Emphasis was placed on planning, implementing, and assessing activities.

The *Groundwater and Environmental Monitoring Quality Assurance and Data Management Plan* (Blewett and Garner 1998) defines the relationship of each element of the environmental monitoring program to key quality and data management requirements. Training requirements, sample custody, procedures, instrument calibration and maintenance, and data review are a few of the subjects discussed in this plan. In 1999, a variety of functions were performed for the environmental monitoring program such as developing DQOs, conducting surveillances, reporting problems, reviewing data, reviewing procedures, and writing and reviewing QA plans.

Field Sampling Quality Control

Data Quality Objectives and Sample Planning

From the point of conception of any sampling program, DQOs play an important role. The number of samples, location of sampling sites, sampling methods, sampling schedules, and coordination of sampling and analytical resources to meet critical completion times were part of the DQOs and are documented in the *Environmental Monitoring Plan* (BJC 1998).

Each sample location and sample collected was assigned a unique identification number which consists of an alphanumeric sequence. Each segment of the sequence was used to designate information concerning the location from which a sample was collected. In order to progress from planning to implementing the DQOs, an analytical statement of work (SOW) for the analytical laboratory was generated from a system within the Paducah Integrated Data System. From this system, the Project Environmental Measurements System (PEMS), an electronic database used for streamlining field-generated and laboratory-generated data, was populated with sample identification numbers, sampling locations, sampling methods, analytical parameters, analytical methods, and container and preservative requirements. This information was used to produce sample bottle/jar labels and chain-of-custody forms for the sampling event.

Field Measurements

Field measurements for the groundwater and surface water monitoring program were collected real-time in the field and consisted of water level measurements, pH, conductivity, flow rates, turbidity, temperature, dissolved oxygen, total residual chlorine, and barometric pressure. Environmental conditions such as temperature and weather were also recorded. Field measurements were taken and downloaded electronically or recorded on appropriate field forms or in logbooks, and input into PEMS on a weekly or other appropriate basis.

Sampling Procedures

Samples were collected using media-specific procedures which are written according to EPA-approved sampling methods. Sample media consisted of surface water, groundwater, sediment, and biota, such as fish or deer. Sample information collected during the sample event consisted of the following: sample identification number, station (or location), data collected, time collected, person who performed the sampling, etc. This information was recorded in the logbooks and on the chain-of-custody form and sample container label, and input directly into PEMS on a weekly or other appropriate basis. Chain-of-custody forms were maintained from the point of sampling, and samples were properly protected until they were placed in the custody of an analytical laboratory.

Field Quality Control Samples

The QC program for both groundwater and environmental monitoring activities specified a minimum target rate of 5%, or one per 20 environmental samples, on field QC samples. Table 11.1 shows the types of QC samples collected and analyzed. Analytical results of field QC samples were evaluated to determine if the sampling event had, in some way, affected the sample results.

Analytical Laboratory Quality Control

Analytical Procedures

When available and appropriate for the sample matrix, SW-846 methods were used for sample analysis. When SW-846 methods were

Table 11.1 Types of Quality Control (QC) Samples

Field QC Samples	Laboratory QC Samples	
Field blanks	Replicates samples	Laboratory control
Field duplicates	Reagent blanks evaluations	Performance
Trip blanks	Matrix spikes duplicates	Matrix spike
Equipment rinseates	Surrogates	

not available, other nationally recognized methods such as those of DOE, EPA, and ASTM were used. Analytical methods were identified in an analytical SOW. Using guidance from EPA, the laboratories document the steps in handling, analysis, and approval of results. Chain-of-custody procedures were followed until a sample was analyzed.

Laboratory Quality Control Samples

Laboratory QC samples were prepared and analyzed as required by the analytical methods used. Typical laboratory QC samples are identified in Table 11.1. If acceptance criteria were not met for the QC samples, then appropriate action, as denoted by the analytical method, was taken or appropriate qualification of the data occurred.

Independent Quality Control

The Paducah Site is directed by DOE and EPA to participate in independent QC programs. The site also participates in voluntary independent programs to improve analytical QC. These programs generate data that are readily recognizable as objective measures, allowing participating laboratories and government agencies a periodic review of their performance. Results that exceed acceptable limits are investigated and documented according to formal procedures. Although participation in certain programs is mandated, the degree of participation is voluntary so that each laboratory can select parameters of particular interest to that facility. These programs are conducted by EPA, DOE, and commercial laboratories.

Laboratory Audits/Sample Management Office

Laboratory audits were periodically performed by the Bechtel Jacobs Company LLC Oak Ridge Sample Management Office (SMO) to ensure the laboratory was in compliance with regulations, procedures, and the contract agreed on between the laboratory and the SMO. Findings were documented and addressed by the audited laboratory through corrective actions.

Data Management

Project Environmental Management System

The data generated by the EM program are stored in PEMS, a consolidated site data system for tracking and managing data. PEMS is used to manage field-generated data; import laboratory-generated data; input data qualifiers identified during the data review process; and transfer data to the Paducah OREIS for reporting. PEMS uses a variety of references and code lists to ensure consistency and to standardize the presentation of data for users.

Electronic Data Deliverables

A "results only" Eletronic Data Deliverable (EDD) is requested for all samples analyzed by the laboratory. The results and qualifier information from the EDD are checked in addition to the format of all fields provided. Discrepancies are immediately reported to the laboratory so that corrections can be made or new EDDs can be issued. Approximately 10 % of the EDDs are checked to verify that the laboratory continues to provide adequate EDDs.

Data Packages

A "forms only" Level III data package is requested from the laboratory when data validation is to be performed on a specific sampling event or media. All data packages received from the fixed-base laboratory are tracked, reviewed, and maintained in a secure environment. The following information is tracked: sample delivery group number; date received; number of samples; sample analyses; receipt of the EDD, if applicable; and comments. The contents of the data package and the chain-of-custody forms are compared and discrepancies are identified. Discrepancies are immediately reported to the laboratory and the data validators. All data packages are forwarded to the PGDP Environmental Management and Enrichment Facilities Document Management Center for permanent storage.

Laboratory Contractual Screening

Laboratory contractual screening is the process of evaluating a set of data against the requirements specified in the analytical SOW to ensure that all requested information is received. The contractual screening includes, but is not limited to, the chain-of-custody form, number of samples, analytes requested, total number of analyses, method used, QC samples analyzed, EDDs, units, holding times, and reporting limits achieved. The contractual screening is conducted electronically upon receipt of data from the analytical laboratory. Any exception to the SOW is identified and documented.

Data Verification, Validation and Assessment

Data verification is the process for comparing a data set against a set standard or contractual requirement. Verification is performed electronically, manually, or by a combination of both. Data verification includes contractual screening and other criteria specific to the data. Data are flagged as necessary. Verification qualifiers are stored in PEMS and transferred with the data to Paducah OREIS.

Data validation is the process performed by a qualified individual for a data set, independent from sampling, laboratory, project management, or other decision-making personnel. Data validation evaluates the laboratory adherence to analytical method requirements. Validation qualifiers are stored in PEMS and transferred with the data to Paducah OREIS. Data are validated at a frequency of 5% of the total data packages from routine sampling events and are applied programmatically. Each data package is validated 100%.

Data assessment is the process for assuring that the type, quality, and quantity of data are appropriate for their intended use. It allows for the determination that a decision (or estimate) can be made with the desired level of confidence, given the quality of the data set. Data assessment follows data verification and data validation (if applicable) and must be performed at a rate of 100% to ensure data are useable. The data assessment is conducted by the technical managers or their designee in conjunction with other project team members. Assessment qualifiers are stored in PEMS and transferred with the data to Paducah OREIS. Data are made available for reporting from Paducah OREIS upon completion of the data assessment, and associated documentation is filed with the project files.

Paducah OREIS

Paducah OREIS is the database used to consolidate data generated by the Environmental Management Program. Data consolidation consists of the activities necessary to prepare the evaluated data for the users. The PEMS files containing the assessed data are transferred from PEMS to Paducah OREIS for future use. The Data Manager is responsible for notifying project team and other data users of the data availability. Data used in reports (e.g., the Quarterly Landfill Reports, the ASER, the Discharge Monitoring Report, and the Report on Biological Monitoring Program) distributed to external agencies are obtained from data in Paducah OREIS and have been through the data review process.

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Glossary

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

activity - See radioactivity.

air stripping - The process of bubbling air through water to remove volatile organic compounds from the water.

alpha particle - A positively charged particle emitted from the nucleus of an atom having the same charge and mass as that of a helium nucleus (two protons and two neutrons).

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

analyte - A constituent or parameter being analyzed.

analytical detection limit - The lowest reasonably accurate concentration of an analyte that can be detected; this value varies depending on the method, instrument, and dilution used.

aquifer - A saturated, permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

aquitard - A geologic unit that inhibits the flow of water.

assimilate - To take up or absorb.

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

beta particle - A negatively charged particle emitted from the nucleus of an atom. 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.

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

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

closure - Formal shutdown of a hazardous waste management facility under Resource Conservation and Recovery Act requirements.

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

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

conductivity - A measure of a material's capacity to convey an electric current. For water this property is related to the total concentration of the ionized substances in water and the temperature at which the measurement is made.

confluence - The point at which two or more streams meet; the point where a tributary joins the main stream.

congener - Any particular member of a class of chemical substances. A specific congener is denoted by a unique chemical structure.

contained landfill - A solid waste site or facility that accepts for disposal of solid waste. The technical requirements for contained landfills are found in 401 KAR 47:080, 48:050, and 48:070 to 48:090.

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.

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; 3.7×10^{-2} disintegrations per second.

daughter - A nuclide formed by the radioactive decay of a parent nuclide.

decay, radioactive - The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide or into a different energy state of the same radionuclide.

dense nonaqueous phase liquid (DNAPL) - The liquid phase of chlorinated organic solvents. These liquids are denser than water and include commonly used industrial compounds such as tetrachloroethylene and trichloroethylene.

derived concentration guide (DCG) - 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 (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and the lens of the eye. The guidelines for radionuclides in air and water are given in DOE Order 5400.5, *Radiation Protection of the Public and the Environment.*

disintegration, nuclear - A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus of an atom.

dose - The energy imparted to matter by ionizing radiation. The unit of absorbed dose is the rad, equal to 0.01 joules per kilogram in any medium.

- **absorbed dose** - The quantity of radiation energy absorbed by an organ divided by the organ's mass. Absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 Gy).
- **dose equivalent** - The product of the absorbed dose (rad) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or sievert) (1 rem = 0.01 Sv).
- **committed dose equivalent** - The calculated total dose equivalent to a tissue or organ over a 50-year period after known intake of a radionuclide into the body. Contributions from external dose are not

included. Committed dose equivalent is expressed in units of rem (or sievert).

- **committed effective dose equivalent** - The sum of the committed dose equivalents to various tissues in the body, each multiplied by the appropriate weighting factor. Committed effective dose equivalent is expressed in units of rem (or sievert).
- **effective dose equivalent** - The sum of the dose equivalents received by all organs or tissues of the body after each one has been multiplied by an appropriate weighting factor. The effective dose equivalent includes the committed effective dose equivalent from internal deposition of radionuclides and the effective dose equivalent attributable to sources external to the body.
- **collective dose equivalent/collective effective dose equivalent** - The sums of the dose equivalents or effective dose equivalents of all individuals in an exposed population within a 50-mile (80-km) radius expressed in units of person-rem (or person-sievert). When the collective dose equivalent of interest is for a specific organ, the units would be organ-rem (or organ-sievert). The 50-mile distance is measured from a point located centrally with respect to major facilities or DOE program activities.

downgradient - In the direction of decreasing hydrostatic head.

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

drinking water standards (DWS) - Federal primary drinking water standards, both proposed and final, as set forth by the EPA.

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

effluent monitoring - The collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying the release of contaminants, assessing radiation exposures to members of the public, and demonstrating 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 incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is that 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 - Exposure to ionizing radiation when the radiation source is located outside the body.

fauna - The population of animals in a given area, environment, formation, or time span.

flora - The population of plants in a given area, environment, formation, or time span.

formation - A mappable unit of consolidated or unconsolidated geologic material of a characteristic lithology or assemblage of lithologies.

gamma ray - High-energy, short-wavelength electromagnetic radiation emitted from the

nucleus of an excited atom. Gamma rays are indentical to X rays except for the source of the emission.

Gaussian puff/plume model - A computer-simulated atmospheric dispersion of a release using a Gaussian (normal) statistical distribution to determine concentrations in air.

grab sample - A sample collected instantaneously with a glass or plastic bottle placed below the water surface to collect surface water samples (also called dip samples).

groundwater, unconfined - Groundwater exposed to the unsaturated zone.

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.

hydrogeology - Hydraulic aspects of site geology.

hydrology - The science dealing with the properties, distribution, and circulation of natural water systems.

in situ - In its original place; field measurements taken without removing the sample from its origin; remediation performed while groundwater remains below the surface.

internal dose factor - A factor used to convert intakes of radionuclides to dose equivalents.

internal radiation - Occurs when natural radionuclides enter the body by ingestion of foods, milk, 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.

- **long-lived isotope** - A radionuclide that decays at such a slow rate that a quantity of it will exist for an extended period (half-life is greater than three years).

- **short-lived isotope** - A radionuclide that decays so rapidly that a given quantity is transformed almost completely into decay products within a short period (half-life is two days or less).

lower limit of detection - The smallest concentration or amount of analyte that can be reliably detected in a sample at a 95% confidence level.

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.

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

milliroentgen (mR) - A measure of X-ray or gamma radiation. The unit is one-thousandth of a roentgen.

minimum detectable concentration - The smallest amount or concentration of a radionuclide that can be distinguished in a sample by a given

measurement system at a preselected counting time and at a given confidence level.

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 - The dose equivalent that is one-thousandth of a rem.

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

nuclide - An atom specified by its 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.

part per billion (ppb) - A unit measure of concentration equivalent to the weight/volume ratio expressed as µg/L or ng/mL.

part per million (ppm) - A unit measure of concentration equivalent to the weight/volume ratio expressed as mg/L.

pathogen - A disease-producing agent; usually refers to living organisms.

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 6, neutral solutions have a pH equal to 7, and basic solutions have a pH greater than 7.

piezometer - An instrument used to measure the hydraulic potential of groundwater at a given point; also, a well designed for this purpose.

polynuclear aromatic hydrocarbon (PAH) - Any organic compound composed of more than one benzene ring.

polychlorinated biphenyl (PCB) - Any chemical substance that is limited to the biphenyl molecule and that has been chlorinated to varying degrees.

process water - Water used within a system process.

purge - To remove water before sampling, generally by pumping or bailing.

quality assurance (QA) - Any action in environmental monitoring to ensure the reliability of monitoring and measurement data.

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

quality factor - The factor by which the absorbed dose (rad) is multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiation, the biological damage to exposed persons. A quality factor is used because some types of radiation, such as alpha particles, are more biologically damaging than others.

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

radiation detection instruments - Devices that detect and record the characteristics of ionizing radiation.

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 - An unstable nuclide capable of spontaneous transformation into other nuclides by changing its nuclear configuration or energy level. This transformation is accompanied by the emission of photons or particles.

reference material - A material or substance with one or more properties that is sufficiently well established and used to calibrate an apparatus, to assess a measurement method, or to assign values to materials.

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 of a problem. See Environmental Restoration.

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

RFI Program - RCRA Facility Investigation Program; EPA-regulated investigation of a solid waste management unit with regard to its potential impact on the environment.

roentgen - A unit of exposure from X-rays or gamma rays. One roentgen equals 2.58 x 10^4 coulombs per kilogram of air.

screen zone - In well construction, the section of a formation that contains the screen, or perforated pipe, that allows water to enter the well.

semivolatile organic analyte (SVOA) - Any organic compound with a high boiling point which will volatilize upon being heated.

sievert (Sv) - The SI (International System of Units) unit of dose equivalent; 1 Sv = 100 rem.

slurry - A suspension of solid particles (sludge) in water.

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

specific conductance - The ability of water to conduct electricity; this ability varies in proportion to the amount of ionized minerals in the water.

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

storm water runoff - Surface streams that appear after precipitation.

strata - Beds, layers, or zones of rocks.

substrate - The substance, base, surface, or medium in which an organism lives and grows.

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, primarily ^{40}K, thorium, and uranium, in the earth's soils. Terrestrial radiation contributes to natural background radiation.

thermoluminescent dosimeter (TLD) - A device used to measure external gamma radiation.

total activity - The total quantity of radioactive decay particles that are emitted from a sample.

total solids - The sum of total dissolved solids and suspended solids.

total suspended particulates - Refers to the concentration of particulates in suspension in the air irrespective of the nature, source, or size of the particulates.

transuranic element (TRU) - An element above uranium in the Periodic Table, that is, with an atomic number greater than 92. All 11 TRUs are produced artificially and are radioactive. They are neptunium, plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium, and lawrencium.

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

upgradient - In the direction of increasing hydrostatic head.

vadose zone - Soil zone located above the water table.

volatile organic compound (VOC) - Any organic compound which has a low boiling point and readily volatilizes into air (e.g., trichloroethane, tetrachloroethylene, and trichloroethylene).

watershed - The region draining into a river, river system, or body of water.

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

wind rose - A diagram in which statistical information concerning direction and speed of the wind at a location is summarized.

Appendix A: Radiation

This appendix gives basic facts about radiation. This information is intended as a basis for understanding normal radiation dose from sources unassociated with the Paducah Site. The McGraw-Hill dictionary 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 1994).

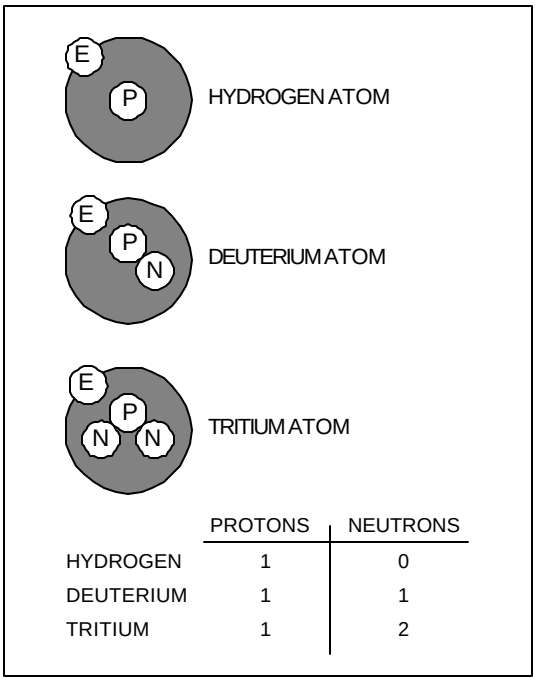
radioactivity - *A* particular type of radiation emitted by a radioactive substance, such as alpha radioactivity (McGraw-Hill 1994).

Radiation occurs naturally; it was not invented, but rather, was 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.

ATOMS AND ISOTOPES

All matter is made up of atoms. An atom is "a unit of matter consisting of a single nucleus surrounded by a number of electrons equal to the number of protons in the nucleus" (ANS 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. Figure 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. ^{234}U has 92 protons and 142 neutrons; ^{235}U has 92 protons and 143 neutrons; and ^{238}U has 92 protons and 146 neutrons.

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.



	PROTONS	NEUTRONS
HYDROGEN	1	0
DEUTERIUM	1	1
TRITIUM	1	2

Figure A.1 Isotopes of the element hydrogen.

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.

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 forms 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. Figure A.2 shows the penetrating potential of different types of ionizing radiation.

Nonionizing Radiation

Nonionizing radiation bounces off of 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.

SOURCES OF RADIATION

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

Background Radiation

Many materials are naturally radioactive. In fact, this naturally occurring radiation is the major source of radiation in the environment. Though 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.

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. In other words, a person in Denver, Colorado, is exposed to more cosmic radiation than a person near Paducah, Kentucky.

Terrestrial Radiation

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

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 ^{212}Th decay series. In addition, the body contains isotopes of potassium (^{40}K), rubidium (^{87}Rb), and carbon (^{14}C).

Human-Made Radiation

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

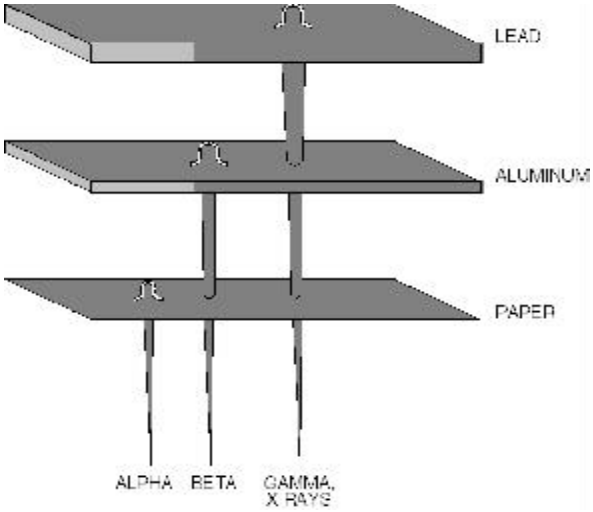


Figure A.2. Penetrating power of radiation. Some types of radiation can be easily shielded against. For example, a sheet of paper is sufficient to stop an alpha particle. Gamma rays can pass through paper but can be stopped by the appropriate amount of lead. Radiation's ability to penetrate is an important consideration in protecting human health. Adequate shielding decreases the power of radiation by absorbing part or all of it.

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, the radiation is essential to the performance of the device. In other products, such as televisions and tobacco products, the radiation occurs incidentally to the product function.

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, diagnostic or therapeutic medical exposures result from X ray beams directed to specific areas of the body. Thus, all body organs generally are not irradiated uniformly. Radiation and radioactive 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.

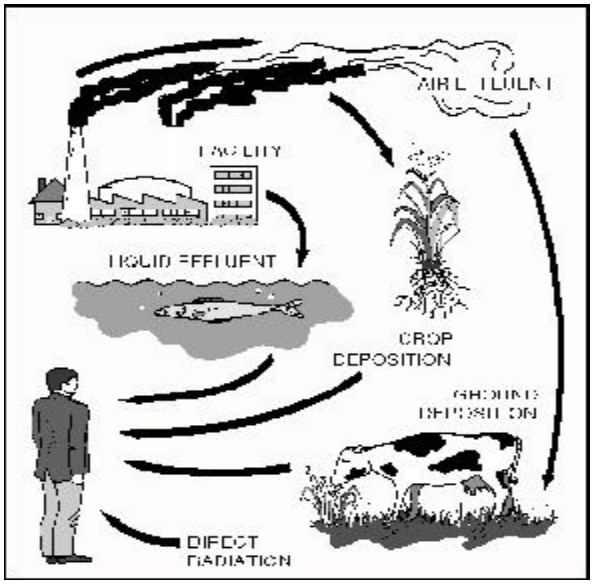


Figure A.3 Possible radiation pathways.

Other Sources

Other sources of radiation include fallout from atmospheric atomic weapons 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 transportation of radioactive materials.

PATHWAYS OF RADIATION

Radiation and radioactive material 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 show up 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 (Figure A.3).

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.

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 g 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 = 3.7E+10 (37,000,000,000) atom disintegrations per second (dps). In the international system of units, 1 dps = 1 becquerel (Bq).

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 = 1 gray (Gy). However, in terms of human health, it is the effect of the absorbed energy that is important because some forms of radiation are more harmful than others as a result of their energy deposition pattern.

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 = 1 Sievert (Sv); 100 mrem = 1 millisievert (mSv).

Dose Terminology

absorbed dose	quantity of radiation energy absorbed by an organ divided by an organ's mass
dose equivalent	absorbed dose to an organ multiplied by a quality factor
effective dose equivalent	single weighted sum of combined dose equivalents received by all organs
committed dose equivalent	effective dose equivalent to an organ over a 50-year period following intake
committed effective dose equivalent	total effective dose equivalent to all organs in the human body over a 50-year period following intake
collective effective dose equivalent	sum of effective dose equivalents of all members of a given population
quality factor	a modifying factor used to adjust for the effect of the type of radiation, for example, alpha particles or gamma rays, on tissue
weighting factor	tissue-specific modifying factor representing the fraction of the total health risk from uniform, whole-body exposure

Figure A.4 Dose terminology.

DOSE

Many terms are used to report dose (Figure A.4). 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 (EDE) and the EDE 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.

Comparison of Dose Levels

A comparison of some dose levels is presented in Table A.1. 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 help the reader become familiar with the type of doses individuals may receive.

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) (NCRP 1987). The average annual dose from cosmic radiation received by residents in the Paducah area is about 45 mrem (0.45 mSv).

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 (NCRP 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. In the Paducah area, background levels of radionuclides in soils are within typical levels indicating that the dose received from terrestrial gamma radiation is within the range of typical reported values discussed previously (DOE 1997).

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) (NCRP 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.

Dose from Consumer Products

The U.S. average annual dose received by an individual from consumer products is about 10 mrem (0.10 mSv) (NCRP 1987).

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. However, the radionuclides used in specific tests are not distributed uniformly throughout the body. In these cases, comparisons are made using the concept of EDE, which relates exposure of organs or body parts to one effective whole-body dose. The average annual EDE 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 (NCRP 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 (NCRP 1989).

Dose from Other Sources

Small doses received by individuals occur as a result of radioactive fallout from atmospheric atomic weapons 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 (NCRP 1987).

A comprehensive 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).

Table A.1 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 by the EPA for exposures from airborne emissions from operations of nuclear fuel cycle facilities, including power plants and uranium mines and mills.
45 mrem (0.45 mSv)	Average yearly dose from cosmic radiation received by people in the Paducah area.
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.
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)	EPA protective action guidelines state that public officials should take emergency action when the dose to a member of the public from a nuclear accident will likely reach this range.
5 rem (0.05 Sv)	Annual limit for occupational exposure of radiation workers set by NRC and DOE.
10 rem (0. 10 Sv)	The BEIR V report estimated that an acute dose at this level would result in a lifetime excess risk of death from cancer, caused by the radiation, of 0.8% (BEIR 1990).
25 rem (0.25 Sv)	EPA guideline for voluntary maximum dose to emergency workers for non-lifesaving work during an emergency.
75 rem (0.75 Sv)	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.

Appendix B: Radionuclide and Chemical Nomenclature

Table B.1 Nomenclature and Half-Life for Radionuclides

Radionuclide	Symbol	Half-life
Americium-241	^{241}Am	432 years
Bismuth-210	^{210}Bi	5.01 days
Cesium-137	^{137}Cs	30.2 years
Cobalt-60	^{60}Co	5.3 years
Lead-206	^{206}Pb	Stable
Lead-210	^{210}Pb	21 years
Lead-214	^{214}Pb	26.8 minutes
Neptunium-237	^{237}Np	2,140,000 years
Plutonium-239	^{239}Pu	24,110 years
Polonium-210	^{210}Po	138.9 days
Polonium-214	^{214}Po	164 microseconds
Polonium-218	^{218}Po	3.05 minutes

Radionuclide	Symbol	Half-life
Potassium-40	^{40}K	1,260,000,000 years
Protactinium-234m	^{234m}Pa	1. 17 minutes
Radium-226	^{226}Ra	1,602 years
Radon-222	^{222}Ra	3.821 days
Technetium-99	^{99}Tc	212,000 years
Thorium-230	^{230}Th	80,000 years
Thorium-231	^{231}Th	25.5 hours
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 B.2 Nomenclature for Elements and Chemical Constituents

Constituent	Symbol	Constituent	Symbol
Aluminum	Al	Manganese	Mn
Ammonia	NH_3	Mercury	Hg
Antimony	Sb	Nickel	Ni
Arsenic	As	Nitrate	NO_3
Barium	Ba	Nitrite	NO_2
Beryllium	Be	Nitrogen	N
Cadmium	Cd	Oxygen	O
Calcium	Ca	Ozone	O_3
Calcium carbonate	$CaCO_3$	Phosphate	PO_4
Carbon	C	Phosphorus	P
Chlorine	Cl	Potassium	K
Chromium	Cr	Radium	Ra
Chromium, hexavalent	Cr^{6+}	Radon	Rn
Cobalt	Co	Selenium	Se
Copper	Cu	Silver	Ag
Fluorine	F	Sodium	Na
Hydrogen fluoride	HF	Sulfate	SO_4
Iron	Fe	Sulfur dioxide	SO_2
Lead	Pb	Thorium	Th
Lithium	Li	Uranium	U
Magnesium	Mg	Zinc	Zn

Appendix C: Data Tables

Notes:

1. Selected results are discussed in the appropriate sections of the text of this report.

2. "ND" means the parameter was not detected. Detection limits are available in the Paducah OREIS database.

3. Monitoring programs often include measurement of extremely low concentrations of radionuclides, below the detection limit of the counting instruments. Less-than-detectable data will produce numerical measurements with values below the detection limit and sometimes negative values. All of the actual values, including those that are negative, are included in the statistical analyses in accordance with DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991).

4. Average values are calculated using the actual result values from the OREIS database, including when results are below the detection level. Where actual result values below the detection level are not available, the detection level is used in the calculations. Therefore, average values reported where any results used were below detection levels are actually lower than reported.

KPDES Radiological Data

Table C.1 Radiological Effluent Data for Outfall 001

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Dissolved Alpha	pCi/L	ND	15.7	6.22	4	1	9.11
Dissolved Beta	pCi/L	24.21	73.75	52.03	4	4	15.98
Suspended Alpha	pCi/L	ND	ND	ND	4	0	5.43
Suspended Beta	pCi/L	ND	13.57	6.00	4	2	8.18
Technetium-99	pCi/L	ND	24.1	14.2	4	2	19.3
Uranium-235	wt %	0.43	0.553	0.471	2	2	

Table C.2 Radiological Effluent Data for Outfall 015

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Dissolved Alpha	pCi/L	42.53	62.53	49.91	3	3	8.03
Dissolved Beta	pCi/L	71.56	221.58	121.82	3	3	9.11
Suspended Alpha	pCi/L	ND	ND	ND	3	0	5.17
Suspended Beta	pCi/L	17.27	26.51	20.85	3	3	7.9
Technetium-99	pCi/L	27	89.7	53.4	3	3	18.8
Uranium-235	wt %	0.3	0.57	0.40	3	3	

KPDES Radiological Data

Table C.3 Radiological Effluent Data for Outfall 017

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Dissolved Alpha	pCi/L	ND	4.71	2.07	4	1	7.84
Dissolved Beta	pCi/L	ND	25.16	14.20	4	3	8.66
Suspended Alpha	pCi/L	ND	ND	ND	4	0	5.18
Suspended Beta	pCi/L	ND	ND	ND	4	0	9.52
Technetium-99	pCi/L	ND	28.7	11.8	4	1	18.8
Uranium-235	wt %				0	1	

Table C.4 Radiological Effluent Data for Outfall 019

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Dissolved Alpha	pCi/L	ND	ND	ND	2	0	6.47
Dissolved Beta	pCi/L	ND	26.76	13.89	2	1	9.91
Suspended Alpha	pCi/L	ND	ND	ND	2	0	5.84
Suspended Beta	pCi/L	ND	8.21	2.14	2	1	9.19
Technetium-99	pCi/L	ND	ND	ND	1	0	16.84
Uranium-235	wt %				0	1	

Table C.5 Radiological Effluent Data for Surface Water Location L1
Upstream Bayou Creek (Background)

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detectable	Maximum of Detection Limits
Dissolved Alpha	pCi/L	ND	41.84	8.531	7	3	6.4
Dissolved Beta	pCi/L	ND	29.56	8.746	7	2	9.8
Gamma Activity	pCi/L	ND	15700	9800	7	3	13.1
Neptunium-237	pCi/L	ND	0.971	0.213	7	1	0.564
Plutonium-239/240	pCi/L	ND	ND	ND	7	0	0.243
Suspended Alpha	pCi/L	ND	ND	ND	7	0	5.47
Suspended Beta	pCi/L	ND	ND	ND	7	0	9.74
Technetium-99	pCi/L	ND	ND	ND	7	0	20
Thorium-230	pCi/L	ND	0.654	0.0344	7	1	1.59

Surface Water Radiological Data

Table C.6 Radiological Effluent Data for Surface Water Location L5
Downstream Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detectable	Maximum of Detection Limits
Alpha Activity	pCi/L	ND	ND	ND	2	0	3.76
Americium-241	pCi/L	ND	ND	ND	1	0	36.9
Beta Activity	pCi/L	ND	19.27	9.63	2	1	6.37
Dissolved Alpha	pCi/L	ND	7.38	3.53	6	2	6.39
Dissolved Beta	pCi/L	ND	53.56	34.13	6	5	17.35
Gamma Activity	pCi/L	77	15100	8940	6	5	42.3
Neptunium-237	pCi/L	ND	ND	ND	7	0	24.9
Plutonium-239/240	pCi/L	ND	ND	ND	7	0	1.19
Suspended Alpha	pCi/L	ND	3.5	0.70	6	1	1.96
Suspended Beta	pCi/L	ND	ND	ND	6	0	9.48
Technetium-99	pCi/L	ND	ND	ND	6	0	19.1
Thorium-230	pCi/L	ND	ND	ND	7	0	0.586

Table C.7 Radiological Effluent Data for Surface Water Location L8
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detectable	Maximum of Detection Limits
Alpha activity	pCi/L	ND	ND	ND	2	0	3.8
Americium-241	pCi/L	ND	ND	ND	1	0	37.2
Beta activity	pCi/L	ND	22.83	11.41	2	1	6.43
Neptunium-237	pCi/L	ND	ND	ND	1	0	25.5
Plutonium-239/240	pCi/L	ND	ND	ND	1	0	0.251
Technetium-99	pCi/L	ND	ND	ND	4	0	17.1
Thorium-230	pCi/L	ND	ND	ND	1	0	0.769

Surface Water Radiological Data

Table C.8 Radiological Effluent Data for Surface Water Location L10
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Alpha Activity	pCi/L	ND	4.51	-7.74	2	1	3.68
Americium-241	pCi/L	ND	ND	ND	1	0	37.2
Beta Activity	pCi/L	ND	ND	ND	2	0	6.25
Dissolved Alpha	pCi/L	ND	9.16	4.71	8	4	4.89
Dissolved Beta	pCi/L	ND	55.89	14.66	8	3	11.81
Gamma Activity	pCi/L	333	15500	8340	8	5	13.5
Neptunium-237	pCi/L	ND	1.69	0.34	9	1	0.506
Plutonium-239/240	pCi/L	ND	ND	ND	9	0	0.241
Suspended Alpha	pCi/L	ND	4.31	1.82	8	2	3.62
Suspended Beta	pCi/L	ND	ND	ND	8	0	9.47
Technetium-99	pCi/L	ND	ND	ND	9	0	19.1
Thorium-230	pCi/L	ND	ND	ND	9	0	0.641
Uranium-235	wt %	0.502	0.502	0.502	1	1	
Uranium-238	pCi/L	6.69	6.69	6.69	1	1	

Table C.9 Radiological Effluent Data for Surface Water Location L11
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Dissolved Alpha	pCi/L	ND	3.42	1.41	7	1	2.95
Dissolved Beta	pCi/L	ND	103.57	21.48	7	3	12.05
Gamma Activity	pCi/L	22.8	15900	7560	7	6	12.7
Neptunium-237	pCi/L	ND	ND	ND	7	0	1.24
Plutonium-239/240	pCi/L	ND	ND	ND	7	0	0.238
Suspended Alpha	pCi/L	ND	ND	ND	7	0	5.05
Suspended Beta	pCi/L	ND	15.34	3.00	7	1	9.47
Technetium-99	pCi/L	ND	29.4	10.0	7	2	18.2
Thorium-230	pCi/L	ND	ND	ND	7	0	1.04

Table C.10 Radiological Effluent Data for Surface Water Location L12
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Technetium-99	pCi/L	ND	44.7	30.1	6	5	19.1

Surface Water Radiological Data

Table C.11 Radiological Effluent Data for Surface Water Location L29
Upstream Ohio River (Reference)

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Dissolved Alpha	pCi/L	ND	5.64	1.34	7	2	6.64
Dissolved Beta	pCi/L	ND	65.75	11.37	7	2	10.96
Gamma Activity	pCi/L	ND	15700	6180	6	5	8.96
Neptunium-237	pCi/L	ND	ND	ND	7	0	1.24
Plutonium-239/240	pCi/L	ND	0.261	0.046	7	1	0.236
Suspended Alpha	pCi/L	ND	ND	ND	7	0	7.76
Suspended Beta	pCi/L	ND	31.66	3.23	7	1	9.14
Technetium-99	pCi/L	ND	19.73	1.92	7	1	16.33
Thorium-230	pCi/L	ND	0.633	0.095	7	1	0.63

Table C.12 Radiological Effluent Data for Surface Water Location L30
Downstream Ohio River

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Dissolved Alpha	pCi/L	ND	ND	ND	2	0	6.74
Dissolved Beta	pCi/L	ND	14.25	8.44	2	1	10.35
Gamma Activity	pCi/L	15400	15400	15400	2	2	27.7
Neptunium-237	pCi/L	ND	0.6	0.378	2	1	1.24
Plutonium-239/240	pCi/L	ND	ND	ND	2	0	0.239
Suspended Alpha	pCi/L	ND	ND	ND	2	0	5.11
Suspended Beta	pCi/L	ND	ND	ND	2	0	8.61
Technetium-99	pCi/L	ND	19.5	13.0	2	1	17.4
Thorium-230	pCi/L	ND	ND	ND	2	0	0.716

Table C.13 Radiological Effluent Data for Surface Water Location L64
Massac Creek (Reference)

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Dissolved Alpha	pCi/L	ND	ND	ND	7	0	5.68
Dissolved Beta	pCi/L	ND	ND	ND	7	0	9.97
Gamma Activity	pCi/L	56.4	15600	9240	7	6	43.1
Neptunium-237	pCi/L	ND	0.584	0.277	7	1	0.72
Plutonium-239/240	pCi/L	ND	ND	ND	7	0	1.18
Suspended Alpha	pCi/L	ND	2.4	0.23	7	1	5.04
Suspended Beta	pCi/L	ND	ND	ND	7	0	9.47
Technetium-99	pCi/L	ND	ND	ND	7	0	19.1
Thorium-230	pCi/L	ND	ND	ND	7	0	0.806

Surface Water Radiological Data

Table C.14 Radiological Effluent Data for Surface Water Location L135
Upstream C-746 S&T closed Landfills

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Alpha activity	pCi/L	ND	ND	ND	4	0	5.65
Beta activity	pCi/L	9.5	28.12	14.44	4	4	7.3

Table C.15 Radiological Effluent Data for Surface Water Location L136
At the C-746 S&T closed Landfills

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Alpha activity	pCi/L	ND	ND	ND	3	0	7.23
Beta activity	pCi/L	13.64	30.97	20.08	3	3	7.77

Table C.16 Radiological Effluent Data for Surface Water Location L137
Downstream of the C-746 S&T closed Landfills

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Alpha activity	pCi/L	ND	ND	ND	3	0	5.61
Beta activity	pCi/L	11.86	18.57	14.30	3	3	7.27

Table C.17 Radiological Effluent Data for Surface Water Location L150
At the C-746 U Landfill

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Alpha activity	pCi/L	ND	ND	ND	3	0	3.91
Beta activity	pCi/L	ND	11.77	6.89	3	2	4.7

Table C.18 Radiological Effluent Data for Surface Water Location L154
Upstream of the C-746 U Landfill

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Alpha activity	pCi/L	ND	3.27	1.59	4	1	2.84
Beta activity	pCi/L	7.75	16.39	12.29	4	4	5.11

Surface Water Radiological Data

Table C.19 Radiological Effluent Data for Surface Water Location L155
Downstream of the C-746-U Landfill

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Alpha activity	pCi/L	ND	ND	ND	4	0	3.65
Beta activity	pCi/L	ND	20.5	9.69	4	3	5.71

Table C.20 Radiological Effluent Data for Surface Water Location L241
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Technetium-99	pCi/L	27.8	79.3	50.3	6	6	20

Table C.21 Radiological Effluent Data for Surface Water Location L306
Downstream Ohio River, Cairo, Illinois

Analysis	Units	Minimum	Maximum	Average	Count	Count of Detections	Maximum of Detection Limits
Dissolved Alpha	pCi/L	ND	ND	ND	2	0	6.23
Dissolved Beta	pCi/L	ND	ND	ND	2	0	11.96
Gamma Activity	pCi/L	11900	16000	13950	2	2	52.2
Neptunium-237	pCi/L	ND	ND	ND	2	0	1.24
Plutonium-239/240	pCi/L	ND	ND	ND	2	0	0.247
Suspended Alpha	pCi/L	ND	ND	ND	2	0	4.26
Suspended Beta	pCi/L	ND	ND	ND	2	0	8.24
Technetium-99	pCi/L	ND	ND	ND	2	0	17.4
Thorium-230	pCi/L	ND	ND	ND	2	0	0.76

Deer Radiological Data

Table C.22 Radiological Analysis of Deer Bone Tissue for 1999
pCi/g

	West Kentucky Wildlife Management Area									Ballard Wildlife Management Area	
Analysis	Deer 1	Deer 1 Dup	Deer 2	Deer 3	Deer 4	Deer 5	Deer 6	Deer 7	Deer 8	Deer 9	Deer 10
Cesium-137	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Neptunium-237	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.013	ND
Plutonium-239/240	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Strontium-90	ND	ND	ND	ND	ND	ND	ND	3.4	3.2	ND	ND
Technetium-99	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-230	0.29	ND	ND	0.015	ND	ND	ND	ND	0.03	ND	0.03
Uranium-234	0.047	ND	ND	ND	ND	0.022	0.029	ND	0.029	ND	ND
Uranium-235	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.018
Uranium-238	ND	ND	ND	0.008	ND	ND	0.012	ND	ND	ND	ND

Table C.23 Radiological Analysis of Deer Liver Tissue for 1999
pCi/g

	West Kentucky Wildlife Management Area									Ballard Wildlife Management Area	
Analysis	Deer 1	Deer 1 Dup	Deer 2	Deer 3	Deer 4	Deer 5	Deer 6	Deer 7	Deer 8	Deer 9	Deer 10
Cesium-137	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Neptunium-237	0.009	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Plutonium-239/240	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Technetium-99	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-230	ND	ND	ND	0.012	ND	ND	ND	0.017	ND	ND	ND
Uranium-234	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Uranium-235	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Uranium-238	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

Table C.24 Radiological Analysis of Deer Thyroid Tissue for 1999
pCi/g

	West Kentucky Wildlife Management Area									Ballard Wildlife Management Area	
Analysis	Deer 1	Deer 1 Dup	Deer 2	Deer 3	Deer 4	Deer 5	Deer 6	Deer 7	Deer 8	Deer 9	Deer 10
Technetium-99	ND	NA	ND	ND	ND	ND	ND	ND	ND	ND	ND

Note: Deer 1 did not have enough thyroid tissue for duplicate analysis

Deer Radiological Data

Table C.25 Radiological Analysis of Deer Muscle Tissue for 1999
pCi/g

	West Kentucky Wildlife Management Area									Ballard Wildlife Management Area	
Analysis	**Deer 1**	**Deer 1 Dup**	**Deer 2**	**Deer 3**	**Deer 4**	**Deer 5**	**Deer 6**	**Deer 7**	**Deer 8**	**Deer 9**	**Deer 10**
Cesium-137	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Neptunium-237	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Plutonium-239/240	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Technetium-99	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-230	ND	0.005	ND	ND	ND	ND	ND	0.005	ND	ND	ND
Uranium-234	ND	0.012	ND	ND	ND	ND	ND	0.02	ND	ND	ND
Uranium-235	ND	ND	ND	0.006	ND	ND	ND	ND	ND	ND	ND
Uranium-238	ND	ND	ND	ND	0.006	ND	ND	ND	ND	ND	ND

Rabbit Radiological Data

Table C.26 Radiological Analysis of Rabbit Muscle Tissue for 1999
pCi/g

Analysis	Rabbit 1	Rabbit 2	Rabbit 3	Rabbit 4	Rabbit 5	Rabbit 6	Rabbit 6 Dup	Rabbit 7	Rabbit 8
Cesium-137	ND	ND	ND	ND	ND	ND	ND	ND	ND
Neptunium-237	ND	ND	ND	ND	ND	ND	ND	ND	ND
Plutonium-239/240	ND	ND	ND	ND	ND	ND	ND	ND	ND
Strontium-90	ND	ND	ND	ND	ND	ND	ND	ND	ND
Technetium-99	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-230	ND	ND	ND	ND	ND	ND	ND	ND	ND
Uranium-234	ND	0.012	ND	ND	ND	ND	ND	ND	ND
Uranium-235	ND	ND	ND	ND	ND	ND	ND	ND	ND
Uranium-238	ND	ND	ND	ND	ND	ND	ND	ND	ND

Direct Gamma Radiation (TLD) Data

Table C.27 Radiological Exposure Due to Gamma Radiation
mR

Location	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Annualized[1]
TLD-1	94	145	120	96	446
TLD-2	135	240	230	180	770
TLD-3	235	380	135	62	797
TLD-4	22	25	25	25	95
TLD-5	24	28	26	26	102
TLD-6	22	24	25	23	92
TLD-7	26	30	30	26	109
TLD-8	--	20	--	19	71
TLD-9	--	27	--	--	89
TLD-10	21	22	25	21	87
TLD-11	23	24	25	24	93
TLD-12	21	23	24	22	88
TLD-13	24	28	27	26	102
TLD-14	20	21	22	21	82
TLD-15	21	21	21	22	83
TLD-16	24	27	27	25	100
TLD-17	20	21	21	20	80
TLD-18	--	23	--	--	75
TLD-19	22	22	23	22	87
TLD-20	24	25	25	25	96
TLD-21	24	29	29	28	107
TLD-22	25	27	28	26	105
TLD-23	23	26	27	24	99
TLD-24	22	23	23	22	88
TLD-25	--	31	32	30	117
TLD-26	26	29	30	26	108

-- = no data

[1] Note: Annualized results represent a summation of the quarters adjusted to account for the number of days of exposure varying from 365.

KPDES Outfalls Non-Radiological Data

Table C.28 Non-Radiological Effluent Data for Outfall 001

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections
Antimony	mg/L	ND	ND	ND	4	0
Arsenic	mg/L	ND	ND	ND	4	0
Beryllium	mg/L	ND	ND	ND	4	0
Cadmium	mg/L	ND	ND	ND	4	0
Calcium hardness	mg/L	10	273	142	8	8
Chlorine, Total Residual	mg/L	ND	0.19	0.033	79	11
Chromium	mg/L	ND	ND	ND	4	0
Conductivity	umho/cm	497	2100	1156	71	71
Copper	mg/L	ND	ND	ND	4	0
Dissolved Oxygen	mg/L	4.95	12.91	8.12	70	70
Flow Rate	mgd	0.5	5	1.9	87	87
Hardness - Total as CaCO3	mg/L	66	464	273	16	16
Iron	mg/L	0.31	0.94	0.50	4	4
Lead	mg/L	ND	ND	ND	4	0
Mercury	mg/L	ND	ND	ND	4	0
Nickel	mg/L	ND	ND	ND	4	0
Oil and Grease	mg/L	ND	ND	ND	52	0
PCB-1016	ug/L	ND	ND	ND	16	0
PCB-1221	ug/L	ND	ND	ND	16	0
PCB-1232	ug/L	ND	ND	ND	16	0
PCB-1242	ug/L	ND	ND	ND	16	0
PCB-1248	ug/L	ND	ND	ND	16	0
PCB-1254	ug/L	ND	ND	ND	16	0
PCB-1260	ug/L	ND	ND	ND	16	0
PCB-1268	ug/L	ND	ND	ND	16	0
pH	Std Unit	6.97	8.75	7.65	84	84
Phosphorous	mg/L	ND	0.29	0.13	51	47
Polychlorinated biphenyl	ug/L	ND	ND	ND	16	0
Selenium	mg/L	ND	ND	ND	4	0
Silver	mg/L	ND	ND	ND	4	0
Temperature	deg F	34	87.9	67	87	87
Thallium	mg/L	ND	ND	ND	4	0
Total Metals	mg/L	ND	ND	ND	3	0
Trichloroethene	ug/L	ND	ND	ND	16	0
Uranium	mg/L	0.001	0.073	0.029	4	4
Zinc	mg/L	ND	ND	ND	4	0

KPDES Outfalls Non-Radiological Data

Table C.29 Non-Radiological Effluent Data for Outfall 015

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections
Antimony	mg/L	ND	ND	ND	3	0
Arsenic	mg/L	ND	ND	ND	3	0
Beryllium	mg/L	ND	ND	ND	3	0
Cadmium	mg/L	ND	ND	ND	3	0
Chromium	mg/L	ND	ND	ND	3	0
Conductivity	umho/cm	1.6	1900	784	8	8
Copper	mg/L	ND	ND	ND	3	0
Dissolved Oxygen	mg/L	6.43	8.75	7.59	8	8
Flow Rate	mgd	0.0007	3.08	0.475	12	12
Hardness - Total as CaCO3	mg/L	68	436	178	8	8
Iron	mg/L	0.901	1.6	1.30	3	3
Lead	mg/L	ND	ND	ND	3	0
Mercury	mg/L	ND	ND	ND	3	0
Nickel	mg/L	ND	ND	ND	3	0
Oil and Grease	mg/L	ND	ND	ND	8	0
PCB-1016	ug/L	ND	ND	ND	9	0
PCB-1221	ug/L	ND	ND	ND	9	0
PCB-1232	ug/L	ND	ND	ND	9	0
PCB-1242	ug/L	ND	ND	ND	9	0
PCB-1248	ug/L	ND	ND	ND	9	0
PCB-1254	ug/L	ND	ND	ND	9	0
PCB-1260	ug/L	ND	ND	ND	9	0
PCB-1268	ug/L	ND	ND	ND	9	0
pH	Std Unit	7.4	7.7	7.5	11	11
Polychlorinated biphenyl	ug/L	ND	ND	ND	9	0
Selenium	mg/L	ND	ND	ND	3	0
Silver	mg/L	ND	ND	ND	3	0
Temperature	deg F	52.1	76.8	64	9	9
Thallium	mg/L	ND	ND	ND	3	0
Total Metals	mg/L	ND	ND	ND	2	0
Uranium	mg/L	0.085	0.26	0.185	3	3
Zinc	mg/L	ND	0.539	0.313	3	1

KPDES Outfalls Non-Radiological Data

Table C.30 Non-Radiological Effluent Data for Outfall 017

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections
Antimony	mg/L	ND	ND	ND	4	0
Arsenic	mg/L	ND	ND	ND	4	0
Beryllium	mg/L	ND	ND	ND	4	0
Cadmium	mg/L	ND	ND	ND	4	0
Chlorine, Total Residual	mg/L	ND	ND	ND	4	0
Chromium	mg/L	ND	ND	ND	4	0
Conductivity	umho/cm	184	705	418	16	16
Copper	mg/L	ND	ND	ND	4	0
Dissolved Oxygen	mg/L	5.09	10.89	7.40	16	16
Flow Rate	mgd	ND	7.85	0.99	20	19
Hardness - Total as CaCO3	mg/L	51	466	169	15	15
Iron	mg/L	0.41	1.42	0.69	4	4
Lead	mg/L	ND	ND	ND	4	0
Mercury	mg/L	ND	ND	ND	4	0
Nickel	mg/L	ND	ND	ND	4	0
Oil and Grease	mg/L	ND	ND	ND	15	0
PCB-1016	ug/L	ND	ND	ND	16	0
PCB-1221	ug/L	ND	ND	ND	16	0
PCB-1232	ug/L	ND	ND	ND	16	0
PCB-1242	ug/L	ND	ND	ND	16	0
PCB-1248	ug/L	ND	ND	ND	16	0
PCB-1254	ug/L	ND	ND	ND	16	0
PCB-1260	ug/L	ND	ND	ND	16	0
PCB-1268	ug/L	ND	ND	ND	16	0
pH	Std Unit	7.52	8.9	7.98	19	19
Polychlorinated biphenyl	ug/L	ND	ND	ND	16	0
Selenium	mg/L	ND	ND	ND	4	0
Silver	mg/L	ND	ND	ND	4	0
Temperature	deg F	52	75	66	17	17
Thallium	mg/L	ND	ND	ND	4	0
Total Metals	mg/L	ND	ND	ND	3	0
Uranium	mg/L	ND	0.007	0.004	4	2
Zinc	mg/L	ND	0.27	0.22	4	1

KPDES Outfalls Non-Radiological Data

Table C.31 Non-Radiological Effluent Data for Outfall 019

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections
Antimony	mg/L	ND	ND	ND	2	0
Arsenic	mg/L	ND	ND	ND	2	0
Beryllium	mg/L	ND	ND	ND	2	0
Cadmium	mg/L	ND	ND	ND	2	0
Chromium	mg/L	ND	ND	ND	2	0
Conductivity	umho/cm	193	488	272	4	4
Copper	mg/L	ND	ND	ND	2	0
Dissolved Oxygen	mg/L	5.74	12.8	8.66	4	4
Flow Rate	mgd	0.02	0.86	0.38	7	7
Hardness - Total as CaCO3	mg/L	73	82	77	2	2
Iron	mg/L	0.256	1.54	0.90	2	2
Lead	mg/L	ND	ND	ND	2	0
Mercury	mg/L	ND	ND	ND	2	0
Nickel	mg/L	ND	ND	ND	2	0
Oil and Grease	mg/L	ND	ND	ND	2	0
PCB-1016	ug/L	ND	ND	ND	2	0
PCB-1221	ug/L	ND	ND	ND	2	0
PCB-1232	ug/L	ND	ND	ND	2	0
PCB-1242	ug/L	ND	ND	ND	2	0
PCB-1248	ug/L	ND	ND	ND	2	0
PCB-1254	ug/L	ND	ND	ND	2	0
PCB-1260	ug/L	ND	ND	ND	2	0
PCB-1268	ug/L	ND	ND	ND	2	0
pH	Std Unit	7.33	8.25	7.84	5	5
Polychlorinated biphenyl	ug/L	ND	ND	ND	2	0
Selenium	mg/L	ND	ND	ND	2	0
Silver	mg/L	ND	ND	ND	2	0
Suspended Solids	mg/L	ND	24	17	2	1
Temperature	deg F	46	72.2	58.7	6	6
Thallium	mg/L	ND	ND	ND	2	0
Total Metals	mg/L	ND	ND	ND	1	0
Uranium	mg/L	ND	ND	ND	2	0
Zinc	mg/L	ND	ND	ND	2	0

Surface Water Non-Radiological Data

Table C.32 Nonradiological Data Summary for Surface Water Location L1
Upstream Bayou Creek (Background)

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
2-Propanol	ug/L	ND	ND	ND	7	0	1000
Acetone	ug/L	ND	ND	ND	7	0	1000
Aluminum	mg/L	ND	ND	ND	7	0	1
Cadmium	mg/L	ND	ND	ND	7	0	0.05
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	ND	ND	ND	7	0	10
Chloride	mg/L	9.6	18.3	15.8	7	7	2
Chromium	mg/L	ND	ND	ND	7	0	0.05
Conductivity	umho/cm	168	285	259	6	6	
Copper	mg/L	ND	ND	ND	7	0	0.1
Dissolved Oxygen	mg/L	3.96	10	7.7	6	6	
Flow Rate	mgd	0.17	0.65	0.48	6	6	
Hardness - Total as CaCO3	mg/L	54	64	57	7	7	15
Iron	mg/L	0.216	0.816	0.429	7	7	0.2
Lead	mg/L	ND	ND	ND	7	0	0.25
Nickel	mg/L	ND	ND	ND	7	0	0.1
PCB-1016	ug/L	ND	ND	ND	7	0	0.17
PCB-1221	ug/L	ND	ND	ND	7	0	0.17
PCB-1232	ug/L	ND	ND	ND	7	0	0.17
PCB-1242	ug/L	ND	ND	ND	7	0	0.17
PCB-1248	ug/L	ND	ND	ND	7	0	0.17
PCB-1254	ug/L	ND	ND	ND	7	0	0.17
PCB-1260	ug/L	ND	ND	ND	7	0	0.17
PCB-1268	ug/L	ND	ND	ND	7	0	0.17
pH	Std Unit	7.2	7.82	7.48	7	7	
Phosphorous	mg/L	ND	0.07	0.05	7	1	0.05
Polychlorinated biphenyl	ug/L	ND	ND	ND	7	0	0.17
Suspended Solids	mg/L	ND	ND	ND	7	0	10
Temperature	deg F	39.4	79.5	62.7	7	7	
Trichloroethene	ug/L	ND	1	1	7	1	1
Uranium	mg/L	ND	ND	ND	7	0	0.001
Zinc	mg/L	ND	ND	ND	7	0	0.2

Surface Water Non-Radiological Data

Table C.33 Nonradiological Data Summary for Surface Water Location L5
Downstream Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
1,1,1-Trichloroethane	ug/L	ND	ND	ND	1	0	5
1,1,2,2-Tetrachloroethane	ug/L	ND	ND	ND	1	0	5
1,1,2-Trichloroethane	ug/L	ND	ND	ND	1	0	5
1,1-Dichloroethane	ug/L	ND	ND	ND	1	0	5
1,1-Dichloroethene	ug/L	ND	ND	ND	1	0	5
1,2-Dibromoethane	ug/L	ND	ND	ND	1	0	5
1,2-Dichloroethane	ug/L	ND	ND	ND	1	0	5
1,2-Dichloropropane	ug/L	ND	ND	ND	1	0	5
2-Butanone	ug/L	ND	ND	ND	1	0	10
2-Hexanone	ug/L	ND	ND	ND	1	0	10
2-Propanol	ug/L	ND	ND	ND	6	0	1000
4-Methyl-2-pentanone	ug/L	ND	ND	ND	1	0	10
Acetone	ug/L	ND	1000	860	7	1	1000
Aluminum	mg/L	ND	ND	ND	6	0	1
Benzene	ug/L	ND	ND	ND	1	0	5
Bromodichloromethane	ug/L	ND	ND	ND	1	0	5
Bromoform	ug/L	ND	ND	ND	1	0	5
Cadmium	mg/L	ND	ND	ND	6	0	0.05
Carbon disulfide	ug/L	ND	ND	ND	1	0	5
Carbon tetrachloride	ug/L	ND	ND	ND	1	0	5
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	ND	ND	ND	6	0	10
Chloride	mg/L	26	155.9	75.6	6	6	2
Chlorobenzene	ug/L	ND	ND	ND	1	0	5
Chloroethane	ug/L	ND	ND	ND	1	0	5
Chloroform	ug/L	ND	ND	ND	1	0	5
Chloromethane	ug/L	ND	ND	ND	1	0	5
Chromium	mg/L	ND	ND	ND	6	0	0.05
Cis-1,2-Dichloroethene	ug/L	ND	ND	ND	1	0	5
Cis-1,3-Dichloropropene	ug/L	ND	ND	ND	1	0	5
Conductivity	umho/cm	291	1400	836	7	7	
Copper	mg/L	ND	ND	ND	6	0	0.1
Dibromochloromethane	ug/L	ND	ND	ND	1	0	5
Dimethylbenzene	ug/L	ND	ND	ND	1	0	15
Dissolved Oxygen	mg/L	6.67	12.05	9.08	7	7	
Ethylbenzene	ug/L	ND	ND	ND	1	0	5
Flow Rate	mgd	1.24	11.9	6.95	7	7	
Hardness - Total as CaCO3	mg/L	70	305	194	6	6	15
Iron	mg/L	ND	0.388	0.272	6	4	0.2
Lead	mg/L	ND	ND	ND	6	0	0.25
Methylene chloride	ug/L	ND	ND	ND	1	0	10
Nickel	mg/L	ND	ND	ND	6	0	0.1

Surface Water Non-Radiological Data

Table C.33 Nonradiological Data Summary for Surface Water Location L5 (Continued)
Downstream Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
PCB-1016	ug/L	ND	ND	ND	7	0	0.17
PCB-1221	ug/L	ND	ND	ND	7	0	0.94
PCB-1232	ug/L	ND	ND	ND	7	0	0.17
PCB-1242	ug/L	ND	ND	ND	7	0	0.17
PCB-1248	ug/L	ND	ND	ND	7	0	0.17
PCB-1254	ug/L	ND	ND	ND	7	0	0.17
PCB-1260	ug/L	ND	ND	ND	7	0	0.17
PCB-1268	ug/L	ND	ND	ND	7	0	0.17
pH	Std Unit	7.25	7.9	7.615	8	8	
Phosphorous	mg/L	0.05	0.13	0.09	6	6	0.05
Polychlorinated biphenyl	ug/L	ND	ND	ND	7	0	0.94
Styrene	ug/L	ND	ND	ND	1	0	5
Suspended Solids	mg/L	ND	12	10	6	1	10
Temperature	deg F	48	85.5	68.3	8	8	
Tetrachloroethene	ug/L	ND	ND	ND	1	0	5
Toluene	ug/L	ND	ND	ND	1	0	5
trans-1,2-Dichloroethene	ug/L	ND	ND	ND	1	0	5
trans-1,3-Dichloropropene	ug/L	ND	ND	ND	1	0	5
Trichloroethene	ug/L	ND	ND	ND	7	0	1
Uranium	mg/L	ND	0.01	0.004	6	5	0.001
Zinc	mg/L	ND	0.28	0.19	6	2	0.2

Surface Water Non-Radiological Data

Table C.34 Nonradiological Data Summary for Surface Water Location L8
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Max. of Detection Limits
1,1,1-Trichloroethane	ug/L	ND	ND	ND	1	0	5
1,1,2,2-Tetrachloroethane	ug/L	ND	ND	ND	1	0	5
1,1,2-Trichloroethane	ug/L	ND	ND	ND	1	0	5
1,1-Dichloroethane	ug/L	ND	ND	ND	1	0	5
1,1-Dichloroethene	ug/L	ND	ND	ND	1	0	5
1,2-Dichloroethane	ug/L	ND	ND	ND	1	0	5
1,2-Dichloropropane	ug/L	ND	ND	ND	1	0	5
2-Butanone	ug/L	ND	ND	ND	1	0	10
2-Hexanone	ug/L	ND	ND	ND	1	0	10
4-Methyl-2-pentanone	ug/L	ND	ND	ND	1	0	10
Acetone	ug/L	15	15	15	1	1	10
Benzene	ug/L	ND	ND	ND	1	0	5
Bromodichloromethane	ug/L	ND	ND	ND	1	0	5
Bromoform	ug/L	ND	ND	ND	1	0	5
Carbon disulfide	ug/L	ND	ND	ND	1	0	5
Carbon tetrachloride	ug/L	ND	ND	ND	1	0	5
Chlorobenzene	ug/L	ND	ND	ND	1	0	5
Chloroethane	ug/L	ND	ND	ND	1	0	5
Chloroform	ug/L	ND	ND	ND	1	0	5
Chloromethane	ug/L	ND	ND	ND	1	0	5
cis-1,2-Dichloroethene	ug/L	ND	ND	ND	1	0	5
cis-1,3-Dichloropropene	ug/L	ND	ND	ND	1	0	5
Conductivity	umho/cm	310	762	454	4	4	
Dibromochloromethane	ug/L	ND	ND	ND	1	0	5
Dimethylbenzene	ug/L	ND	ND	ND	1	0	15
Dissolved Oxygen	mg/L	6.97	9.96	9.06	4	4	
Ethylbenzene	ug/L	ND	ND	ND	1	0	5
Flow Rate	mgd	6.3	10.2	8.3	4	4	
Methylene chloride	ug/L	ND	ND	ND	1	0	10
PCB-1016	ug/L	ND	ND	ND	1	0	0.12
PCB-1221	ug/L	ND	ND	ND	1	0	0.94
PCB-1232	ug/L	ND	ND	ND	1	0	0.14
PCB-1242	ug/L	ND	ND	ND	1	0	0.16
PCB-1248	ug/L	ND	ND	ND	1	0	0.13
PCB-1254	ug/L	ND	ND	ND	1	0	0.07
PCB-1260	ug/L	ND	ND	ND	1	0	0.15
PCB-1268	ug/L	ND	ND	ND	1	0	0.07
pH	Std Unit	7	7.37	7.14	4	4	
Polychlorinated biphenyl	ug/L	ND	ND	ND	1	0	0.94
Styrene	ug/L	ND	ND	ND	1	0	5
Temperature	deg F	56.3	75.7	66.6	4	4	
Tetrachloroethene	ug/L	ND	ND	ND	1	0	5
Toluene	ug/L	ND	ND	ND	1	0	5
trans-1,2-Dichloroethene	ug/L	ND	ND	ND	1	0	5
trans-1,3-Dichloropropene	ug/L	ND	ND	ND	1	0	5
Trichloroethene	ug/L	ND	ND	ND	4	0	1

Surface Water Non-Radiological Data

Table C.35 Nonradiological Data Summary for Surface Water Location L10
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
1,1,1-Trichloroethane	ug/L	ND	ND	ND	1	0	5
1,1,2,2-Tetrachloroethane	ug/L	ND	ND	ND	1	0	5
1,1,2-Trichloroethane	ug/L	ND	ND	ND	1	0	5
1,1-Dichloroethane	ug/L	ND	ND	ND	1	0	5
1,1-Dichloroethene	ug/L	ND	ND	ND	1	0	5
1,2-Dichloroethane	ug/L	ND	ND	ND	1	0	5
1,2-Dichloropropane	ug/L	ND	ND	ND	1	0	5
2-Butanone	ug/L	ND	ND	ND	1	0	10
2-Hexanone	ug/L	ND	ND	ND	1	0	10
2-Propanol	ug/L	ND	ND	ND	8	0	1000
4-Methyl-2-pentanone	ug/L	ND	ND	ND	1	0	10
Acetone	ug/L	ND	1000	890	9	1	1000
Aluminum	mg/L	ND	2.34	1.15	8	3	1
Benzene	ug/L	ND	ND	ND	1	0	5
Bromodichloromethane	ug/L	ND	ND	ND	1	0	5
Bromoform	ug/L	ND	ND	ND	1	0	5
Cadmium	mg/L	ND	ND	ND	8	0	0.05
Carbon disulfide	ug/L	ND	ND	ND	1	0	5
Carbon tetrachloride	ug/L	ND	ND	ND	1	0	5
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	ND	ND	ND	8	0	10
Chloride	mg/L	22.1	41.8	31.1	8	8	2
Chlorobenzene	ug/L	ND	ND	ND	1	0	5
Chloroethane	ug/L	ND	ND	ND	1	0	5
Chloroform	ug/L	ND	ND	ND	1	0	5
Chloromethane	ug/L	ND	ND	ND	1	0	5
Chromium	mg/L	ND	ND	ND	8	0	0.05
cis-1,2-Dichloroethene	ug/L	ND	ND	ND	1	0	5
cis-1,3-Dichloropropene	ug/L	ND	ND	ND	1	0	5
Conductivity	umho/cm	259	484	369	7	7	
Copper	mg/L	ND	ND	ND	8	0	0.1
Dibromochloromethane	ug/L	ND	ND	ND	1	0	5
Dimethylbenzene	ug/L	ND	ND	ND	1	0	15
Dissolved Oxygen	mg/L	5.2	11.1	8.1	7	7	
Ethylbenzene	ug/L	ND	ND	ND	1	0	5
Flow Rate	mgd	0.51	6.51	2.16	6	6	
Hardness - Total as CaCO3	mg/L	53	116	90.5	8	8	15
Iron	mg/L	ND	1.7	0.8	8	7	0.2
Lead	mg/L	ND	ND	ND	8	0	0.25
Methylene chloride	ug/L	ND	ND	ND	1	0	10
Nickel	mg/L	ND	ND	ND	8	0	0.1

Surface Water Non-Radiological Data

Table C.35 Nonradiological Data Summary for Surface Water Location L10 (Continued)
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
PCB-1016	ug/L	ND	ND	ND	9	0	0.17
PCB-1221	ug/L	ND	ND	ND	9	0	0.94
PCB-1232	ug/L	ND	ND	ND	9	0	0.17
PCB-1242	ug/L	ND	ND	ND	9	0	0.17
PCB-1248	ug/L	ND	ND	ND	9	0	0.17
PCB-1254	ug/L	ND	ND	ND	9	0	0.17
PCB-1260	ug/L	ND	ND	ND	9	0	0.17
PCB-1268	ug/L	ND	ND	ND	9	0	0.17
pH	Std Unit	7.39	8.44	7.67	8	8	
Phosphorous	mg/L	0.08	0.44	0.21	8	8	0.05
Polychlorinated biphenyl	ug/L	ND	ND	ND	9	0	0.94
Styrene	ug/L	ND	ND	ND	1	0	5
Suspended Solids	mg/L	ND	30	13	8	2	10
Temperature	deg F	47	79.5	66.9	8	8	
Tetrachloroethene	ug/L	ND	ND	ND	1	0	5
Toluene	ug/L	ND	ND	ND	1	0	5
trans-1,2-Dichloroethene	ug/L	ND	ND	ND	1	0	5
trans-1,3-Dichloropropene	ug/L	ND	ND	ND	1	0	5
Trichloroethene	ug/L	ND	ND	ND	9	0	1
Uranium	mg/L	0.001	0.02	0.01	11	9	0.001
Zinc	mg/L	ND	ND	ND	8	0	0.2

Surface Water Non-Radiological Data

Table C.36 Nonradiological Data Summary for Surface Water Location L11
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
2-Propanol	ug/L	ND	ND	ND	7	0	1000
Acetone	ug/L	ND	ND	ND	7	0	1000
Aluminum	mg/L	ND	1.22	0.69	7	1	1
Cadmium	mg/L	ND	ND	ND	7	0	0.05
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	ND	ND	ND	6	0	10
Chloride	mg/L	19.4	43.4	30.9	7	7	2
Chromium	mg/L	ND	ND	ND	7	0	0.05
Conductivity	umho/cm	253	435	367	6	6	
Copper	mg/L	ND	ND	ND	7	0	0.1
Dissolved Oxygen	mg/L	5.8	9.31	7.82	6	6	
Flow Rate	mgd	0.61	2.31	1.45	6	6	
Hardness - Total as CaCO3	mg/L	73	91	83	7	7	15
Iron	mg/L	0.272	1.29	0.61	7	7	0.2
Lead	mg/L	ND	ND	ND	7	0	0.25
Nickel	mg/L	ND	ND	ND	7	0	0.1
PCB-1016	ug/L	ND	ND	ND	7	0	0.17
PCB-1221	ug/L	ND	ND	ND	7	0	0.17
PCB-1232	ug/L	ND	ND	ND	7	0	0.17
PCB-1242	ug/L	ND	ND	ND	7	0	0.17
PCB-1248	ug/L	ND	ND	ND	7	0	0.17
PCB-1254	ug/L	ND	ND	ND	7	0	0.17
PCB-1260	ug/L	ND	ND	ND	7	0	0.17
PCB-1268	ug/L	ND	ND	ND	7	0	0.17
pH	Std Unit	7.2	7.79	7.45	7	7	
Phosphorous	mg/L	ND	0.21	0.11	7	6	0.05
Polychlorinated biphenyl	ug/L	ND	ND	ND	7	0	0.17
Suspended Solids	mg/L	ND	ND	ND	7	0	10
Temperature	deg F	43.5	78.2	57.8	7	7	
Trichloroethene	ug/L	ND	ND	ND	7	0	1
Uranium	mg/L	0.002	0.011	0.005	8	7	0.001
Zinc	mg/L	ND	ND	ND	7	0	0.2

Surface Water Non-Radiological Data

Table C.37 Nonradiological Data Summary for Surface Water Location L12
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Conductivity	umho/cm	321	432	376	5	5	
Dissolved Oxygen	mg/L	6.3	14.5	9.3	5	5	
Flow Rate	mgd	0.03	2.51	1.51	5	5	
pH	Std Unit	6.9	6.97	6.94	5	5	
Temperature	deg F	52.6	74.7	64.3	5	5	
Trichloroethene	ug/L	1	9	4	6	6	1

Surface Water Non-Radiological Data

Table C.38 Nonradiological Data Summary for Surface Water Location L29
Upstream Ohio River

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
2-Propanol	ug/L	ND	ND	ND	7	0	1000
Acetone	ug/L	ND	ND	ND	7	0	1000
Aluminum	mg/L	ND	2.35	1.22	7	4	1
Bromodichloromethane	ug/L	6	6	6	1	1	5
Cadmium	mg/L	ND	ND	ND	7	0	0.05
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	ND	ND	ND	7	0	10
Chloride	mg/L	9.2	32.2	18.0	7	7	2
Chloroform	ug/L	19	19	19	1	1	5
Chromium	mg/L	ND	ND	ND	7	0	0.05
Conductivity	umho/cm	203	347	287	6	6	
Copper	mg/L	ND	ND	ND	7	0	0.1
Dissolved Oxygen	mg/L	3.31	10.06	6.35	6	6	
Hardness - Total as CaCO3	mg/L	35	129	101	7	7	15
Iron	mg/L	0.213	1.85	0.96	7	7	0.2
Lead	mg/L	ND	ND	ND	7	0	0.25
Nickel	mg/L	ND	ND	ND	7	0	0.1
PCB-1016	ug/L	ND	ND	ND	7	0	0.17
PCB-1221	ug/L	ND	ND	ND	7	0	0.17
PCB-1232	ug/L	ND	ND	ND	7	0	0.17
PCB-1242	ug/L	ND	ND	ND	7	0	0.17
PCB-1248	ug/L	ND	ND	ND	7	0	0.17
PCB-1254	ug/L	ND	ND	ND	7	0	0.17
PCB-1260	ug/L	ND	ND	ND	7	0	0.17
PCB-1268	ug/L	ND	ND	ND	7	0	0.17
pH	Std Unit	7.31	7.8	7.576	7	7	
Phosphorous	mg/L	ND	0.13	0.08	7	6	0.05
Polychlorinated biphenyl	ug/L	ND	ND	ND	7	0	0.17
Suspended Solids	mg/L	12	38	26	7	7	10
Temperature	deg F	49	84.3	66.6	7	7	
Trichloroethene	ug/L	ND	ND	ND	7	0	1
Uranium	mg/L	ND	ND	ND	7	0	0.001
Zinc	mg/L	ND	ND	ND	7	0	0.2

Surface Water Non-Radiological Data

Table C.39 Nonradiological Data Summary for Surface Water Location L30
Downstream Ohio River

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
2-Propanol	ug/L	ND	ND	ND	2	0	1000
Acetone	ug/L	ND	ND	ND	2	0	1000
Aluminum	mg/L	ND	0.82	0.51	2	1	0.2
Cadmium	mg/L	ND	ND	ND	2	0	0.01
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	ND	ND	ND	2	0	10
Chloride	mg/L	17.4	33.2	25.3	2	2	2
Chromium	mg/L	ND	ND	ND	2	0	0.05
Conductivity	umho/cm	254	380	317	2	2	
Copper	mg/L	ND	ND	ND	2	0	0.05
Dissolved Oxygen	mg/L	9.17	10.25	9.71	2	2	
Hardness - Total as CaCO3	mg/L	86	119	102	2	2	15
Iron	mg/L	0.301	0.796	0.548	2	2	0.2
Lead	mg/L	ND	ND	ND	2	0	0.2
Nickel	mg/L	ND	ND	ND	2	0	0.05
PCB-1016	ug/L	ND	ND	ND	2	0	0.17
PCB-1221	ug/L	ND	ND	ND	2	0	0.17
PCB-1232	ug/L	ND	ND	ND	2	0	0.17
PCB-1242	ug/L	ND	ND	ND	2	0	0.17
PCB-1248	ug/L	ND	ND	ND	2	0	0.17
PCB-1254	ug/L	ND	ND	ND	2	0	0.17
PCB-1260	ug/L	ND	ND	ND	2	0	0.17
PCB-1268	ug/L	ND	ND	ND	2	0	0.17
pH	Std Unit	7.7	7.8	7.7	2	2	
Phosphorous	mg/L	0.05	0.07	0.06	2	2	0.05
Polychlorinated biphenyl	ug/L	ND	ND	ND	2	0	0.17
Suspended Solids	mg/L	18	20	19	2	2	10
Temperature	deg F	55.9	63.1	59.5	2	2	
Trichloroethene	ug/L	ND	ND	ND	2	0	1
Uranium	mg/L	ND	ND	ND	2	0	0.001
Zinc	mg/L	ND	ND	ND	2	0	0.2

Surface Water Non-Radiological Data

Table C.40 Nonradiological Data Summary for Surface Water Location L64
Massac Creek (Background)

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
2-Propanol	ug/L	ND	ND	ND	7	0	1000
Acetone	ug/L	ND	ND	ND	7	0	1000
Aluminum	mg/L	ND	ND	ND	7	0	1
Cadmium	mg/L	ND	ND	ND	7	0	0.05
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	ND	ND	ND	6	0	10
Chloride	mg/L	9.5	16.6	13.7	7	7	2
Chromium	mg/L	ND	ND	ND	7	0	0.05
Conductivity	umho/cm	133	145.3	138.5	6	6	
Copper	mg/L	ND	ND	ND	7	0	0.1
Dissolved Oxygen	mg/L	5.8	10.3	8.3	6	6	
Flow Rate	mgd	0.27	11.9	5.2	6	6	
Hardness - Total as CaCO3	mg/L	32	179	59	7	7	15
Iron	mg/L	0.664	1.01	0.84	7	7	0.2
Lead	mg/L	ND	ND	ND	7	0	0.25
Nickel	mg/L	ND	ND	ND	7	0	0.1
PCB-1016	ug/L	ND	ND	ND	7	0	0.17
PCB-1221	ug/L	ND	ND	ND	7	0	0.17
PCB-1232	ug/L	ND	ND	ND	7	0	0.17
PCB-1242	ug/L	ND	ND	ND	7	0	0.17
PCB-1248	ug/L	ND	ND	ND	7	0	0.17
PCB-1254	ug/L	ND	ND	ND	7	0	0.17
PCB-1260	ug/L	ND	ND	ND	7	0	0.17
PCB-1268	ug/L	ND	ND	ND	7	0	0.17
pH	Std Unit	6.8	7.31	7.11	7	7	
Phosphorous	mg/L	ND	ND	ND	7	0	0.05
Polychlorinated biphenyl	ug/L	ND	ND	ND	7	0	0.17
Suspended Solids	mg/L	ND	ND	ND	7	0	10
Temperature	deg F	42.5	74.5	56.7	7	7	
Trichloroethene	ug/L	ND	ND	ND	7	0	1
Uranium	mg/L	ND	ND	ND	7	0	0.001
Zinc	mg/L	ND	ND	ND	7	0	0.2

Surface Water Non-Radiological Data

Table C.41 Nonradiological Data Summary for Surface Water Location L135
Upstream C-746-S&T Closed Landfills

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Chemical Oxygen Demand (COD)	mg/L	ND	34	28	4	2	25
Chloride	mg/L	2.6	6.8	4.2	4	4	2
Conductivity	umho/cm	110.7	122.2	114.5	3	3	field
Conductivity	umho/cm	95.6	122.5	109.0	2	2	0.5
Dissolved Oxygen	mg/L	7.55	7.82	7.64	3	3	
Dissolved Solids	mg/L	ND	113	107	5	3	100
Flow Rate	mgd	0.03	12.4	3.23	4	4	
Iron	mg/L	0.521	3.57	1.686	4	4	0.2
pH	Std Unit	6.92	7.7	7.46	4	4	
Sodium	mg/L	ND	5.07	2.96	4	2	5
Sulfate	mg/L	4.8	7.1	6.2	4	4	5
Suspended Solids	mg/L	ND	52	25	4	2	10
Temperature	deg F	45.6	62.6	51.3	3	3	
Total Organic Carbon (TOC)	mg/L	8	15	10	4	4	1.5
Total Solids	mg/L	108	185	134	4	4	25
Uranium	mg/L	0.002	0.004	0.0025	4	4	0.001

Table C.42 Nonradiological Data Summary for Surface Water Location L136
Upstream C-746-S&T Closed Landfills

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Chemical Oxygen Demand (COD)	mg/L	ND	28	26	3	2	25
Chloride	mg/L	3.5	15.2	7.8	3	3	2
Conductivity	umho/cm	137.2	842	489.6	2	2	field
Conductivity	umho/cm	196	835	515	2	2	0.5
Dissolved Oxygen	mg/L	8.2	8.36	8.28	2	2	
Dissolved Solids	mg/L	112	586	247	4	4	100
Flow Rate	mgd	0.3	0.89	0.61	3	3	
Iron	mg/L	ND	0.75	0.41	3	2	0.2
pH	Std Unit	7.54	7.95	7.75	3	3	
Sodium	mg/L	ND	21.1	9.4	3	1	5
Sulfate	mg/L	12.9	197.4	75.5	3	3	5
Suspended Solids	mg/L	ND	ND	ND	3	0	10
Temperature	deg F	45.8	68.6	57.2	2	2	
Total Organic Carbon (TOC)	mg/L	7	11	9	3	3	1.5
Total Solids	mg/L	119	625	299	3	3	25
Uranium	mg/L	ND	0.01	0.004	3	2	0.001

Surface Water Non-Radiological Data

Table C.43 Nonradiological Data Summary for Surface Water Location L137
Downstream C-746-S&T Closed Landfills

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Chemical Oxygen Demand (COD)	mg/L	ND	33	30	3	2	25
Chloride	mg/L	ND	5.2	3.8	3	2	2
Conductivity	umho/cm	96	118	107	2	2	field
Conductivity	umho/cm	95	97.8	96.4	2	2	0.5
Dissolved Oxygen	mg/L	8.99	12.32	10.65	2	2	
Dissolved Solids	mg/L	100	127	118	4	4	100
Flow Rate	mgd	1.52	12.67	5.27	3	3	
Iron	mg/L	3.37	3.71	3.54	3	3	0.2
pH	Std Unit	6.92	7.8	7.28	3	3	
Sodium	mg/L	ND	5	3	3	1	5
Sulfate	mg/L	5.8	9.3	7.6	3	3	5
Suspended Solids	mg/L	41	107	83	3	3	10
Temperature	deg F	44.7	62.6	53.6	2	2	
Total Organic Carbon (TOC)	mg/L	9	16	11	3	3	1.5
Total Solids	mg/L	166	323	230	3	3	100
Uranium	mg/L	ND	0.003	0.002	3	2	0.001

Table C.44 Nonradiological Data Summary for Surface Water Location L150
At the C-746-U Landfill

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Chemical Oxygen Demand (COD)	mg/L	ND	29	26	3	1	25
Chloride	mg/L	ND	2.83	2.28	3	1	2
Conductivity	umho/cm	67.1	249	170	4	4	0.5
Dissolved Oxygen	mg/L	6.26	8.88	7.57	2	2	
Dissolved Solids	mg/L	ND	147	116	3	1	100
Flow Rate	mgd	0.01	0.11	0.04	3	3	
Iron	mg/L	0.273	0.66	0.48	3	3	0.2
pH	Std Unit	7.33	8.96	7.93	3	3	
Sodium	mg/L	ND	3.88	2.68	3	2	2
Sulfate	mg/L	7.5	23.2	14.9	3	3	5
Suspended Solids	mg/L	ND	10	10	3	1	10
Temperature	deg F	46.5	60.4	53.45	2	2	
Total Organic Carbon (TOC)	mg/L	2.8	12	7.4	3	3	1.5
Total Solids	mg/L	ND	183	129	3	2	100
Uranium	mg/L	ND	0.001	0.001	3	1	0.001

Surface Water Non-Radiological Data

Table C.45 Nonradiological Data Summary for Surface Water Location L154
Upstream of the C-746-U Landfill

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Chemical Oxygen Demand (COD)	mg/L	ND	37	29	4	2	25
Chloride	mg/L	ND	4.2	3.4	4	3	2
Conductivity	umho/cm	100.6	132	114	4	4	0.5
Dissolved Oxygen	mg/L	5.3	11.38	9.35	3	3	
Dissolved Solids	mg/L	ND	151	131	4	3	100
Flow Rate	mgd	1.25	6.66	4.21	4	4	
Iron	mg/L	1.96	4.92	3.09	4	4	0.2
pH	Std Unit	7.13	7.53	7.36	4	4	
Sodium	mg/L	ND	4.24	2.59	4	2	2
Sulfate	mg/L	7.8	12.7	9.1	4	4	5
Suspended Solids	mg/L	ND	38	23	4	3	10
Temperature	deg F	45	64.7	51.6	3	3	
Total Organic Carbon (TOC)	mg/L	9.1	14	10.9	4	4	1.5
Total Solids	mg/L	155	183	169	4	4	100
Uranium	mg/L	ND	0.004	0.002	4	2	0.001

Table C.46 Nonradiological Data Summary for Surface Water Location L155
Downstream of the C-746-U Landfill

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Chemical Oxygen Demand (COD)	mg/L	ND	28	26	4	2	25
Chloride	mg/L	2.5	21.6	9.4	4	4	2
Conductivity	umho/cm	78.9	254	159	6	6	0.5
Dissolved Oxygen	mg/L	7	10.97	8.91	3	3	
Dissolved Solids	mg/L	116	145	125	4	4	100
Flow Rate	mgd	1.11	36	17	4	4	
Iron	mg/L	0.324	4.23	2.63	4	4	0.2
pH	Std Unit	6.89	7.9	7.33	4	4	
Sodium	mg/L	3.1	28.9	12.0	4	4	2
Sulfate	mg/L	9.2	40.2	24.9	4	4	5
Suspended Solids	mg/L	ND	82	38	4	3	10
Temperature	deg F	46.8	73.3	60.2	3	3	
Total Organic Carbon (TOC)	mg/L	3.3	11	6.9	4	4	1.5
Total Solids	mg/L	153	207	179	4	4	100
Uranium	mg/L	0.002	0.012	0.005	4	4	0.001

Surface Water Non-Radiological Data

Table C.47 Nonradiological Data Summary for Surface Water Location L241
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
Conductivity	umho/cm	267	445	336	5	5	
Dissolved Oxygen	mg/L	7.13	12.23	10.06	5	5	
Flow Rate	mgd	0.86	2.8	1.4	5	5	
pH	Std Unit	6.76	6.92	6.86	5	5	
Temperature	deg F	44.4	74.5	62.3	5	5	
Trichloroethene	ug/L	15	51	34	6	6	1

Surface Water Non-Radiological Data

Table C.48 Nonradiological Data Summary for Surface Water Location L306
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Number of Detections	Maximum of Detection Limits
2-Propanol	ug/L	ND	ND	ND	2	0	1000
Acetone	ug/L	ND	ND	ND	2	0	1000
Aluminum	mg/L	ND	0.327	0.263	2	1	0.2
Cadmium	mg/L	ND	ND	ND	2	0	0.01
Carbonaceous Biochemical Oxygen Demand (CBOD)	mg/L	ND	ND	ND	2	0	10
Chloride	mg/L	18.8	38.3	28.5	2	2	2
Chromium	mg/L	ND	ND	ND	2	0	0.05
Conductivity	umho/cm	270	405	337	2	2	
Copper	mg/L	ND	ND	ND	2	0	0.05
Dissolved Oxygen	mg/L	10.04	10.49	10.26	2	2	
Hardness - Total as CaCO3	mg/L	92	133	112	2	2	15
Iron	mg/L	ND	0.332	0.266	2	1	0.2
Lead	mg/L	ND	ND	ND	2	0	0.2
Nickel	mg/L	ND	ND	ND	2	0	0.05
PCB-1016	ug/L	ND	ND	ND	2	0	0.17
PCB-1221	ug/L	ND	ND	ND	2	0	0.17
PCB-1232	ug/L	ND	ND	ND	2	0	0.17
PCB-1242	ug/L	ND	ND	ND	2	0	0.17
PCB-1248	ug/L	ND	ND	ND	2	0	0.17
PCB-1254	ug/L	ND	ND	ND	2	0	0.17
PCB-1260	ug/L	ND	ND	ND	2	0	0.17
PCB-1268	ug/L	ND	ND	ND	2	0	0.17
pH	Std Unit	7.6	7.7	7.6	2	2	
Phosphorous	mg/L	ND	0.05	0.05	2	1	0.05
Polychlorinated biphenyl	ug/L	ND	ND	ND	2	0	0.17
Suspended Solids	mg/L	ND	10	10	2	1	10
Temperature	deg F	51.4	63.2	57.3	2	2	
Trichloroethene	ug/L	ND	ND	ND	2	0	1
Uranium	mg/L	ND	ND	ND	2	0	0.001
Zinc	mg/L	ND	ND	ND	2	0	0.2

Deer Non-Radiological Data

Table C.49 Analysis of Deer Liver Tissue for 1999
mg/Kg

	West Kentucky Wildlife Management Area									Ballard Wildlife Management Area	
Analysis	Deer 1	Deer 1 Dup	Deer 2	Deer 3	Deer 4	Deer 5	Deer 6	Deer 7	Deer 8	Deer 9	Deer 10
Aluminum	3.66	4.16	4.44	4.21	11.2	23	4.25	3	2.6	3.6	2.82
Antimony	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Barium	0.471	0.403	0.799	0.534	0.734	1.27	0.216	0.139	ND	0.166	0.195
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	ND	0.341	ND	ND	0.415	ND	ND	0.271	ND	ND	ND
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	67.2	52.8	1.83	9.06	45.5	1.68	92.6	44.2	67.9	19.4	14.9
Iron	77.3	152	244	297	117	399	112	149	78.2	142	112
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	3.51	4.31	0.474	1.68	4.14	0.369	5.9	4.11	4.32	4.84	3.9
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	ND	14.2	1	ND	ND	ND	ND	ND	3.69	ND	ND
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	0.343	ND	0.321	ND	0.261	ND	ND	0.325	ND	ND	0.293
Zinc	37.1	38	26.8	25.1	41.6	19.9	36	37.7	40.3	35.1	37

Deer Non-Radiological Data

Table C.50 Analysis of Deer Muscle Tissue for 1999
mg/Kg

	West Kentucky Wildlife Management Area									Ballard Wildlife Management Area	
Analysis	**Deer 1**	**Deer 1 Dup**	**Deer 2**	**Deer 3**	**Deer 4**	**Deer 5**	**Deer 6**	**Deer 7**	**Deer 8**	**Deer 9**	**Deer 10**
Aluminum	2.76	ND	ND	1.96	ND	5.37	3.03	ND	13.4	3.94	3.92
Antimony	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Barium	0.473	ND	ND	ND	ND	0.437	ND	ND	ND	ND	ND
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0189	ND
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	2	1.45	1.57	2.1	1.55	2.2	1.83	1.78	2.37	1.97	1.97
Iron	35.2	34.4	32.5	36.2	33.9	40.1	39.3	41	28.5	54.2	40.1
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	0.133	0.0954	0.111	0.175	0.11	0.285	0.205	0.207	0.192	0.245	0.223
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	ND	ND	ND	ND	0.949	ND	ND	ND	1.49	ND	ND
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	1.7	ND	ND	ND	ND	ND	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.32
Zinc	16.2	15.7	13	14.1	16.3	18.8	21.4	14.8	17.4	22	14.8

Table C.51 Analysis of Deer Fat Tissue for 1999
ug/Kg

	West Kentucky Wildlife Management Area									Ballard Wildlife Management Area	
Analysis	**Deer 1**	**Deer 1 Dup**	**Deer 2**	**Deer 3**	**Deer 4**	**Deer 5**	**Deer 6**	**Deer 7**	**Deer 8**	**Deer 9**	**Deer 10**
PCB-1016	ND	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND
PCB-1221	ND	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND
PCB-1232	ND	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND
PCB-1242	ND	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND
PCB-1248	ND	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND
PCB-1254	ND	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND
PCB-1260	ND	NA	ND	ND	NA	ND	ND	ND	ND	ND	ND
Lipids	47%	NA	51.6%	36.3%	NA	79%	62%	65.8%	49.6	54.4%	44.1%

Note: Deer 4 did not have sufficient fat for analysis, Deer 1 did not have enough fat for duplicate analysis

Rabbit Non-Radiological Data

Table C.52 Analysis of Rabbit Muscle Tissue for 1999
mg/Kg

	West Kentucky Wildlife Management Area								
Analysis	**Rabbit 1**	**Rabbit 2**	**Rabbit 3**	**Rabbit 4**	**Rabbit 5**	**Rabbit 6**	**Rabbit 6 Dup**	**Rabbit 7**	**Rabbit 8**
Aluminum	2.21	ND	2.92	ND	1.99	ND	2.16	3.89	2.67
Antimony	ND	ND	ND	ND	ND	ND	ND	ND	ND
Arsenic	ND	ND	ND	ND	ND	ND	ND	ND	ND
Barium	ND	ND	ND	ND	ND	ND	1.46	ND	ND
Beryllium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cadmium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chromium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cobalt	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	0.704	0.687	0.984	0.984	1.23	0.997	0.959	0.566	ND
Iron	21.1	12.3	18.6	14.8	16.5	15.2	17.9	14.3	18.6
Lead	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	0.204	0.45	0.297	0.167	0.576	0.372	0.475	0.146	0.236
Mercury	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND	ND	0.499	ND
Thallium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Vanadium	ND	ND	ND	ND	ND	ND	ND	ND	ND
Zinc	11.6	17.4	12.7	10.9	10.2	13.2	12.7	9.37	8.59

Table C.53 Analysis of Rabbit Fat Tissue for 1999

	West Kentucky Wildlife Management Area								
Analysis	**Rabbit 1**	**Rabbit 2**	**Rabbit 3**	**Rabbit 4**	**Rabbit 5**	**Rabbit 6**	**Rabbit 6 Dup**	**Rabbit 7**	**Rabbit 8**
PCB-1016	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1221	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1232	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1242	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1248	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1254	ND	ND	ND	ND	ND	ND	ND	ND	ND
PCB-1260	ND	ND	ND	ND	ND	ND	ND	ND	ND
Lipids	9.64%	26.99%	20.64%	95.16%	37.99%	74.21%	46.25%	8.23%	ND

Note: Rabbit 8 did not have sufficient fat for analysis

DOE Special Investigations Data

Sediment

Table C.54 Sediment at DOESS-2

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	1252.98	1378.68	1315.83	2
Americium-241	pCi/g	9.43	9.43	9.43	1
Beta activity	pCi/g	594.97	608.29	601.63	2
Cesium-137	pCi/g	10.9	10.9	10.9	1
Neptunium-237	pCi/g	8.73	8.73	8.73	1
PCB-1248	ug/kg	7500	7500	7500	1
PCB-1254	ug/kg	5500	5500	5500	1
PCB-1260	ug/kg	1400	1400	1400	1
Plutonium-239/240	pCi/g	41.6	41.6	41.6	1
Polychlorinated biphenyl	ug/kg	14400	14400	14400	1
Technetium-99	pCi/g	477	477	477	1
Thorium-230	pCi/g	594	594	594	1
Uranium	pCi/g	98.7	98.7	98.7	1
Uranium-235	wt %	0.64	0.64	0.64	1

Table C.55 Sediment at DOESS-3

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	664.54	742.07	703.305	2
Beta activity	pCi/g	1015.16	1027.53	1021.345	2
Cesium-137	pCi/g	0.097	0.097	0.097	1
PCB-1260	ug/kg	500	500	500	1
Plutonium-239/240	pCi/g	0.283	0.283	0.283	1
Polychlorinated biphenyl	ug/kg	500	500	500	1
Technetium-99	pCi/g	406	406	406	1
Thorium-230	pCi/g	3.17	3.17	3.17	1
Uranium	pCi/g	473	473	473	1
Uranium-235	wt %	0.29	0.29	0.29	1

Table C.56 Sediment at DOESS-5

Analysis	Units	Minimum	Maximum	Average	Detected Count
Thorium-230	pCi/g	0.129	0.129	0.129	1
Uranium	pCi/g	1.18	1.18	1.18	1

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Table C.57 Sediment at DOESS-7

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	5.92	7.65	6.785	2
Beta activity	pCi/g	3.53	3.53	3.53	1
Technetium-99	pCi/g	1.03	1.03	1.03	1
Thorium-230	pCi/g	0.0649	0.0649	0.0649	1
Uranium	pCi/g	1.41	1.41	1.41	1

Table C.58 Sediment at DOESS-8

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	8.66	8.66	8.66	1
Beta activity	pCi/g	4.2	4.24	4.22	2
Plutonium-239/240	pCi/g	0.0138	0.0138	0.0138	1
Technetium-99	pCi/g	0.237	0.237	0.237	1
Thorium-230	pCi/g	0.329	0.329	0.329	1
Uranium	pCi/g	2.07	2.07	2.07	1

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Table C.59 Sediment Data at JP-0013

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.8188	0.8188	0.8188	1
Alpha activity	pCi/g	46.02	46.02	46.02	1
Beryllium	mg/kg	0.68	0.68	0.68	1
Beta activity	pCi/g	65.85	65.85	65.85	1
Bismuth-212	pCi/g	0.7243	0.7243	0.7243	1
Bismuth-214	pCi/g	0.8725	0.8725	0.8725	1
Cesium-137	pCi/g	0.183	0.183	0.183	1
Chromium	mg/kg	42.2	42.2	42.2	1
Lead-212	pCi/g	0.774	0.774	0.774	1
Lead-214	pCi/g	0.8365	0.8365	0.8365	1
Neptunium-237	pCi/g	0.126	0.13	0.128	2
Plutonium-239/240	pCi/g	0.06	0.115	0.0875	2
Potassium-40	pCi/g	10.6	10.6	10.6	1
Protactinium-231	pCi/g	0.6862	0.6862	0.6862	1
Protactinium-234m	pCi/g	15.4	15.4	15.4	1
Radium-223	pCi/g	0.1903	0.1903	0.1903	1
Technetium-99	pCi/g	42.7	42.7	42.7	1
Thallium-208	pCi/g	0.19	0.19	0.19	1
Thorium-228	pCi/g	0.491	0.491	0.491	1
Thorium-230	pCi/g	1.25	1.25	1.25	1
Thorium-232	pCi/g	0.203	0.533	0.368	2
Uranium	mg/kg	50	50	50	1
Uranium	pCi/g	29.2	29.2	29.2	1
Uranium-234	pCi/g	10	11.3	10.65	2
Uranium-235	pCi/g	0.62	0.62	0.62	1
Uranium-235	wt %	0.55	0.55	0.55	1
Uranium-238	pCi/g	17	17.3	17.15	2

Table C.60 Sediment Data at JP-0015

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.5378	0.5378	0.5378	1
Alpha activity	pCi/g	12.24	12.24	12.24	1
Beta activity	pCi/g	8.62	8.62	8.62	1
Bismuth-212	pCi/g	0.5602	0.5602	0.5602	1
Bismuth-214	pCi/g	0.6279	0.6279	0.6279	1
Cesium-137	pCi/g	0.512	0.512	0.512	1
Chromium	mg/kg	13	13	13	1
Lead-212	pCi/g	0.5023	0.5023	0.5023	1
Lead-214	pCi/g	0.6715	0.6715	0.6715	1
Plutonium-239/240	pCi/g	0.041	0.07	0.0555	2
Potassium-40	pCi/g	9.41	9.41	9.41	1
Protactinium-231	pCi/g	0.6009	0.6009	0.6009	1
Protactinium-234m	pCi/g	3.1	3.1	3.1	1

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Table C.60 Sediment Data at JP-0015 (Continued)

Analysis	Units	Minimum	Maximum	Average	Detected Count
Thorium-228	pCi/g	0.443	0.443	0.443	1
Thorium-230	pCi/g	0.707	0.707	0.707	1
Thorium-232	pCi/g	0.2438	0.471	0.3574	2
Uranium	mg/kg	8.2	8.2	8.2	1
Uranium	pCi/g	4.67	4.67	4.67	1
Uranium-234	pCi/g	1.43	1.5	1.465	2
Uranium-235	pCi/g	0.081	0.081	0.081	1
Uranium-235	wt %	0.43	0.43	0.43	1
Uranium-238	pCi/g	2.8	3.16	2.98	2

Table C.61 Sediment at JP-0016

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.4971	0.6338	0.5654	2
Alpha activity	pCi/g	17.15	17.15	17.15	1
Beryllium	mg/kg	0.58	0.65	0.62	2
Beta activity	pCi/g	31.7	31.7	31.7	1
Bismuth-212	pCi/g	0.442	0.491	0.466	2
Bismuth-214	pCi/g	0.5918	0.6183	0.6050	2
Cesium-137	pCi/g	1.947	2.043	1.995	2
Chromium	mg/kg	14.7	16	15.3	2
Lead-212	pCi/g	0.3789	0.6168	0.4978	2
Lead-214	pCi/g	0.5769	0.6021	0.5895	2
Neptunium-237	pCi/g	0.058	0.073	0.068	3
Plutonium-239/240	pCi/g	0.066	0.711	0.375	4
Potassium-40	pCi/g	7.998	8.452	8.225	2
Protactinium-233	pCi/g	0.076	0.076	0.076	1
Protactinium-234m	pCi/g	7.501	7.501	7.501	1
Thallium-208	pCi/g	0.2038	0.2038	0.2038	1
Thorium-228	pCi/g	0.405	0.498	0.451	2
Thorium-230	pCi/g	2.18	2.65	2.41	2
Thorium-232	pCi/g	0.2604	0.465	0.3818	3
Uranium	mg/kg	26	31	28	2
Uranium	pCi/g	11.8	12.1	11.9	2
Uranium-234	pCi/g	3.12	4.4	3.63	4
Uranium-235	pCi/g	0.21	0.28	0.24	2
Uranium-235	wt %	0.38	0.42	0.40	2
Uranium-238	pCi/g	8.22	11	9.12	4

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Table C.62 Sediment at JP-0018

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.4773	0.4773	0.4773	1
Alpha activity	pCi/g	43.1	43.1	43.1	1
Beryllium	mg/kg	0.85	0.85	0.85	1
Beta activity	pCi/g	196.33	196.33	196.33	1
Bismuth-212	pCi/g	0.8681	0.8681	0.8681	1
Bismuth-214	pCi/g	0.6729	0.6729	0.6729	1
Cesium-137	pCi/g	0.2117	0.2117	0.2117	1
Chromium	mg/kg	226	226	226	1
Lead-212	pCi/g	0.4068	0.4068	0.4068	1
Lead-214	pCi/g	0.6693	0.6693	0.6693	1
Neptunium-237	pCi/g	0.14	0.14	0.14	1
PCB-1242	ug/kg	8800	8800	8800	1
PCB-1254	ug/kg	4200	4200	4200	1
PCB-1260	ug/kg	3100	3100	3100	1
Polychlorinated biphenyl	ug/kg	16100	16100	16100	1
Potassium-40	pCi/g	5.441	5.441	5.441	1
Protactinium-234m	pCi/g	188	188	188	1
Thorium-228	pCi/g	0.372	0.372	0.372	1
Thorium-230	pCi/g	0.367	0.367	0.367	1
Thorium-232	pCi/g	0.2448	0.386	0.3154	2
Uranium	mg/kg	561	561	561	1
Uranium	pCi/g	202	202	202	1
Uranium-234	pCi/g	17.9	20	18.95	2
Uranium-235	pCi/g	2.6	2.6	2.6	1
Uranium-235	wt %	0.2	0.2	0.2	1
Uranium-238	pCi/g	182	188	185	2

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Table C.63 Sediment at JP-0019

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	1.147	1.147	1.147	1
Alpha activity	pCi/g	2330.1	2330.1	2330.1	1
Beryllium	mg/kg	1.11	1.11	1.11	1
Beta activity	pCi/g	4158.01	4158.01	4158.01	1
Bismuth-212	pCi/g	1.563	1.563	1.563	1
Bismuth-214	pCi/g	1.179	1.179	1.179	1
Cesium-137	pCi/g	0.8882	0.8882	0.8882	1
Chromium	mg/kg	185	185	185	1
Lead-212	pCi/g	0.8146	0.8146	0.8146	1
Lead-214	pCi/g	1.097	1.097	1.097	1
PCB-1254	ug/kg	7300	7300	7300	1
PCB-1260	ug/kg	11000	11000	11000	1
Plutonium-239/240	pCi/g	0.0609	0.19	0.12545	2
Polychlorinated biphenyl	ug/kg	18300	18300	18300	1
Potassium-40	pCi/g	11.07	11.07	11.07	1
Protactinium-234m	pCi/g	2806	2806	2806	1
Strontium-90	pCi/g	3.2	3.2	3.2	1
Technetium-99	pCi/g	13.5	13.5	13.5	1
Thallium-208	pCi/g	0.3686	0.3686	0.3686	1
Thorium-228	pCi/g	0.425	0.425	0.425	1
Thorium-230	pCi/g	0.684	0.684	0.684	1
Thorium-232	pCi/g	0.474	0.474	0.474	1
Uranium	mg/kg	4097	4097	4097	1
Uranium	pCi/g	2490	2490	2490	1
Uranium-234	pCi/g	140	198	169	2
Uranium-235	pCi/g	15	15	15	1
Uranium-235	wt %	0.2	0.2	0.2	1
Uranium-238	pCi/g	1375	2270	1822.5	2

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Table C.64 Sediment at JP-0045

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.5055	0.5055	0.5055	1
Alpha activity	pCi/g	18.93	18.93	18.93	1
Beta activity	pCi/g	29.72	29.72	29.72	1
Bismuth-212	pCi/g	0.6028	0.6028	0.6028	1
Bismuth-214	pCi/g	0.6046	0.6046	0.6046	1
Cesium-137	pCi/g	0.06315	0.06315	0.06315	1
Chromium	mg/kg	23.7	23.7	23.7	1
Lead-212	pCi/g	0.4256	0.4256	0.4256	1
Lead-214	pCi/g	0.6085	0.6085	0.6085	1
Neptunium-237	pCi/g	0.08729	0.11	0.098645	2
Plutonium-239/240	pCi/g	0.019	0.0653	0.04215	2
Potassium-40	pCi/g	7.949	7.949	7.949	1
Protactinium-234m	pCi/g	4.469	4.469	4.469	1
Technetium-99	pCi/g	15.3	15.3	15.3	1
Thorium-228	pCi/g	0.29	0.29	0.29	1
Thorium-230	pCi/g	0.583	0.583	0.583	1
Thorium-232	pCi/g	0.2044	0.287	0.2457	2
Uranium	mg/kg	18	18	18	1
Uranium	pCi/g	9.22	9.22	9.22	1
Uranium-234	pCi/g	3.3	3.73	3.515	2
Uranium-235	pCi/g	0.18	0.18	0.18	1
Uranium-235	wt %	0.58	0.58	0.58	1
Uranium-238	pCi/g	5.3	6	5.65	2

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Table C.65 Sediment at JP-0046

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.654	0.654	0.654	1
Alpha activity	pCi/g	26.48	26.48	26.48	1
Beryllium	mg/kg	0.59	0.59	0.59	1
Beta activity	pCi/g	28.62	28.62	28.62	1
Bismuth-212	pCi/g	0.5443	0.5443	0.5443	1
Bismuth-214	pCi/g	0.7622	0.7622	0.7622	1
Cesium-137	pCi/g	0.1383	0.1383	0.1383	1
Chromium	mg/kg	31.3	31.3	31.3	1
Lead-210	pCi/g	2.071	2.071	2.071	1
Lead-212	pCi/g	0.7218	0.7218	0.7218	1
Lead-214	pCi/g	0.7446	0.7446	0.7446	1
Neptunium-237	pCi/g	0.045	0.045	0.045	1
PCB-1260	ug/kg	100	100	100	1
Polychlorinated biphenyl	ug/kg	100	100	100	1
Potassium-40	pCi/g	9.788	9.788	9.788	1
Protactinium-231	pCi/g	0.4753	0.4753	0.4753	1
Protactinium-234m	pCi/g	12.57	12.57	12.57	1
Technetium-99	pCi/g	10	10	10	1
Thallium-208	pCi/g	0.2178	0.2178	0.2178	1
Thorium-228	pCi/g	0.508	0.508	0.508	1
Thorium-230	pCi/g	1.02	1.02	1.02	1
Thorium-232	pCi/g	0.1218	0.496	0.3089	2
Uranium	mg/kg	32	32	32	1
Uranium	pCi/g	21.8	21.8	21.8	1
Uranium-234	pCi/g	5.6	7.48	6.54	2
Uranium-235	pCi/g	0.31	0.31	0.31	1
Uranium-235	wt %	0.48	0.48	0.48	1
Uranium-238	pCi/g	11	13.9	12.45	2

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Table C.66 Sediment at JP-0057

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.2468	0.2468	0.2468	1
Alpha activity	pCi/g	32.68	32.68	32.68	1
Beta activity	pCi/g	31.7	31.7	31.7	1
Bismuth-214	pCi/g	0.3561	0.3561	0.3561	1
Cesium-137	pCi/g	0.07042	0.07042	0.07042	1
Chromium	mg/kg	12.2	12.2	12.2	1
Lead-212	pCi/g	0.2088	0.2088	0.2088	1
Lead-214	pCi/g	0.3464	0.3464	0.3464	1
Mercury	mg/kg	0.33	0.33	0.33	1
Neptunium-237	pCi/g	0.083	0.1054	0.0942	2
Plutonium-239/240	pCi/g	0.32	0.336	0.328	2
Potassium-40	pCi/g	2.854	2.854	2.854	1
Radium-223	pCi/g	0.1027	0.1027	0.1027	1
Thorium-228	pCi/g	0.176	0.176	0.176	1
Thorium-230	pCi/g	11.1	11.1	11.1	1
Thorium-232	pCi/g	0.0845	0.232	0.15825	2
Uranium	mg/kg	21	21	21	1
Uranium	pCi/g	13.2	13.2	13.2	1
Uranium-234	pCi/g	4.9	5.2	5.05	2
Uranium-235	pCi/g	0.3	0.3	0.3	1
Uranium-235	wt %	0.53	0.53	0.53	1
Uranium-238	pCi/g	7	7.97	7.485	2

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Table C.67 Sediment at JP-0061

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.2172	0.2172	0.2172	1
Alpha activity	pCi/g	17.09	17.09	17.09	1
Americium-241	pCi/g	0.116	0.116	0.116	1
Beta activity	pCi/g	28.38	28.38	28.38	1
Bismuth-212	pCi/g	0.2595	0.2595	0.2595	1
Bismuth-214	pCi/g	0.334	0.334	0.334	1
Cesium-137	pCi/g	0.106	0.106	0.106	1
Chromium	mg/kg	23.1	23.1	23.1	1
Lead-212	pCi/g	0.1532	0.1532	0.1532	1
Lead-214	pCi/g	0.3372	0.3372	0.3372	1
Mercury	mg/kg	0.78	0.78	0.78	1
Neptunium-237	pCi/g	0.109	0.14	0.1245	2
PCB-1260	ug/kg	200	200	200	1
Plutonium-239/240	pCi/g	0.135	0.15	0.1425	2
Polychlorinated biphenyl	ug/kg	200	200	200	1
Potassium-40	pCi/g	3.13	3.13	3.13	1
Protactinium-234m	pCi/g	5.28	5.28	5.28	1
Technetium-99	pCi/g	6.12	6.12	6.12	1
Thorium-228	pCi/g	0.0882	0.0882	0.0882	1
Thorium-230	pCi/g	1.02	1.02	1.02	1
Thorium-232	pCi/g	0.09086	0.09086	0.09086	1
Uranium	mg/kg	17	17	17	1
Uranium	pCi/g	11.3	11.3	11.3	1
Uranium-234	pCi/g	4.5	4.76	4.63	2
Uranium-235	pCi/g	0.18	0.18	0.18	1
Uranium-235	wt %	0.61	0.61	0.61	1
Uranium-238	pCi/g	5.8	6.32	6.06	2

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Table C.68 Sediment at JP-0062

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.5372	0.5372	0.5372	1
Beryllium	mg/kg	0.56	0.56	0.56	1
Bismuth-212	pCi/g	0.4239	0.4239	0.4239	1
Bismuth-214	pCi/g	0.7268	0.7268	0.7268	1
Cesium-137	pCi/g	0.116	0.116	0.116	1
Chromium	mg/kg	16.4	16.4	16.4	1
Lead-212	pCi/g	0.5423	0.5423	0.5423	1
Lead-214	pCi/g	0.7546	0.7546	0.7546	1
Neptunium-237	pCi/g	0.027	0.027	0.027	1
Plutonium-239/240	pCi/g	0.029	0.029	0.029	1
Potassium-40	pCi/g	9.89	9.89	9.89	1
Protactinium-231	pCi/g	0.5727	0.5727	0.5727	1
Protactinium-234m	pCi/g	3.27	3.27	3.27	1
Technetium-99	pCi/g	6.94	6.94	6.94	1
Thorium-228	pCi/g	0.386	0.386	0.386	1
Thorium-230	pCi/g	1.1	1.1	1.1	1
Thorium-232	pCi/g	0.2577	0.408	0.33285	2
Uranium	mg/kg	8.4	8.4	8.4	1
Uranium	pCi/g	6.86	6.86	6.86	1
Uranium-234	pCi/g	2.3	2.7	2.5	2
Uranium-235	pCi/g	0.11	0.11	0.11	1
Uranium-235	wt %	0.57	0.57	0.57	1
Uranium-238	pCi/g	2.8	4.01	3.405	2

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Table C.69 Sediment at JP-0063

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228		0.4573	0.4573	0.4573	1
Beryllium	mg/kg	0.57	0.57	0.57	1
Beta activity	pCi/g	12.16	12.16	12.16	1
Bismuth-212	pCi/g	0.5047	0.5047	0.5047	1
Bismuth-214	pCi/g	0.6188	0.6188	0.6188	1
Cesium-137	pCi/g	0.135	0.135	0.135	1
Chromium	mg/kg	11.7	11.7	11.7	1
Lead-212	pCi/g	0.4447	0.4447	0.4447	1
Lead-214	pCi/g	0.6666	0.6666	0.6666	1
Plutonium-238	pCi/g	0.18	0.18	0.18	1
Potassium-40	pCi/g	8.7	8.7	8.7	1
Protactinium-234m	pCi/g	1.14	1.14	1.14	1
Thorium-228	pCi/g	0.391	0.391	0.391	1
Thorium-230	pCi/g	0.365	0.365	0.365	1
Thorium-232	pCi/g	0.2872	0.382	0.3346	2
Uranium	mg/kg	3	3	3	1
Uranium-234	pCi/g	0.94	0.94	0.94	1
Uranium-235	pCi/g	0.074	0.074	0.074	1
Uranium-235	wt %				0
Uranium-238	pCi/g	1	1	1	1

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Table C.70 Sediment at JP-0066

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.6088	0.6088	0.6088	1
Alpha activity	pCi/g	17.4	17.4	17.4	1
Beta activity	pCi/g	16.1	16.1	16.1	1
Bismuth-212	pCi/g	0.8046	0.8046	0.8046	1
Bismuth-214	pCi/g	0.8795	0.8795	0.8795	1
Cesium-137	pCi/g	0.1797	0.1797	0.1797	1
Chromium	mg/kg	14.7	14.7	14.7	1
Cobalt-56	pCi/g	0.01884	0.01884	0.01884	1
Lead-212	pCi/g	0.5911	0.5911	0.5911	1
Lead-214	pCi/g	0.9073	0.9073	0.9073	1
Neptunium-237	pCi/g	0.067	0.067	0.067	1
Plutonium-239/240	pCi/g	0.061	0.0857	0.07335	2
Potassium-40	pCi/g	6.583	6.583	6.583	1
Protactinium-231	pCi/g	0.4612	0.4612	0.4612	1
Protactinium-233	pCi/g	0.1151	0.1151	0.1151	1
Protactinium-234m	pCi/g	3.98	3.98	3.98	1
Thorium-228	pCi/g	0.33	0.33	0.33	1
Thorium-230	pCi/g	0.523	0.523	0.523	1
Thorium-232	pCi/g	0.3182	0.342	0.3301	2
Uranium	mg/kg	13	13	13	1
Uranium	pCi/g	7.35	7.35	7.35	1
Uranium-234	pCi/g	2.4	3.4	2.9	2
Uranium-235	pCi/g	0.17	0.17	0.17	1
Uranium-235	wt %	0.46	0.46	0.46	1
Uranium-238	pCi/g	4.4	4.81	4.605	2

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Table C.71 Sediment at JP-0071

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	1.233	1.233	1.233	1
Alpha activity	pCi/g	204.27	204.27	204.27	1
Americium-241	pCi/g	1.8	1.8	1.8	1
Beta activity	pCi/g	152.03	152.03	152.03	1
Bismuth-212	pCi/g	1.448	1.448	1.448	1
Bismuth-214	pCi/g	2.673	2.673	2.673	1
Cesium-137	pCi/g	1.701	1.701	1.701	1
Chromium	mg/kg	63.6	63.6	63.6	1
Lead-212	pCi/g	1.36	1.36	1.36	1
Lead-214	pCi/g	2.905	2.905	2.905	1
Mercury	mg/kg	0.25	0.25	0.25	1
Neptunium-237	pCi/g	1.123	1.2	1.1615	2
PCB-1254	ug/kg	700	700	700	1
PCB-1260	ug/kg	500	500	500	1
Plutonium-238	pCi/g	0.12	0.12	0.12	1
Plutonium-239/240	pCi/g	5.93	6.8	6.365	2
Polychlorinated biphenyl	ug/kg	1200	1200	1200	1
Potassium-40	pCi/g	8.315	8.315	8.315	1
Protactinium-231	pCi/g	1.325	1.325	1.325	1
Protactinium-233	pCi/g	0.5243	0.5243	0.5243	1
Radium-223	pCi/g	0.5516	0.5516	0.5516	1
Technetium-99	pCi/g	94.4	94.4	94.4	1
Thorium-228	pCi/g	1.4	1.4	1.4	1
Thorium-230	pCi/g	127	127	127	1
Thorium-232	pCi/g	0.773	1.76	1.2665	2
Uranium	mg/kg	37	37	37	1
Uranium	pCi/g	30.5	30.5	30.5	1
Uranium-234	pCi/g	9.4	10.9	10.15	2
Uranium-235	pCi/g	0.39	0.39	0.39	1
Uranium-235	wt %	0.5	0.5	0.5	1
Uranium-238	pCi/g	12	19	15.5	2

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Table C.72 Sediment at JP-0072

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	3.413	3.413	3.413	1
Alpha activity	pCi/g	807.9	807.9	807.9	1
Americium-241	pCi/g	7.004	7.004	7.004	1
Beryllium	mg/kg	0.59	0.59	0.59	1
Beta activity	pCi/g	622.98	622.98	622.98	1
Bismuth-212	pCi/g	3.609	3.609	3.609	1
Bismuth-214	pCi/g	6.608	6.608	6.608	1
Cesium-137	pCi/g	6.61	6.61	6.61	1
Chromium	mg/kg	256	256	256	1
Lead-212	pCi/g	3.656	3.656	3.656	1
Lead-214	pCi/g	7.347	7.347	7.347	1
Mercury	mg/kg	1.01	1.01	1.01	1
Neptunium-237	pCi/g	4.381	6.4	5.3905	2
PCB-1242	ug/kg	900	900	900	1
PCB-1254	ug/kg	1200	1200	1200	1
PCB-1260	ug/kg	1500	1500	1500	1
Plutonium-238	pCi/g	0.57	0.576	0.573	2
Plutonium-239/240	pCi/g	26.7	29	27.85	2
Polychlorinated biphenyl	ug/kg	3600	3600	3600	1
Potassium-40	pCi/g	10.7	10.7	10.7	1
Protactinium-233	pCi/g	2.115	2.115	2.115	1
Protactinium-234m	pCi/g	72.17	72.17	72.17	1
Radium-223	pCi/g	2.813	2.813	2.813	1
Technetium-99	pCi/g	421	421	421	1
Thorium-228	pCi/g	3.72	3.72	3.72	1
Thorium-230	pCi/g	386	386	386	1
Thorium-232	pCi/g	1.957	4.2	3.0785	2
Uranium	mg/kg	260	260	260	1
Uranium	pCi/g	143	143	143	1
Uranium-234	pCi/g	54.5	67	60.75	2
Uranium-235	pCi/g	3.7	3.7	3.7	1
Uranium-235	wt %	0.54	0.54	0.54	1
Uranium-238	pCi/g	85.3	87	86.15	2

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Table C.73 Sediment at JP-0077

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	1.171	1.171	1.171	1
Alpha activity	pCi/g	338.23	338.23	338.23	1
Americium-241	pCi/g	4.914	4.914	4.914	1
Beta activity	pCi/g	327.9	327.9	327.9	1
Bismuth-212	pCi/g	1.204	1.204	1.204	1
Bismuth-214	pCi/g	1.354	1.354	1.354	1
Cesium-137	pCi/g	2.665	2.665	2.665	1
Chromium	mg/kg	190	190	190	1
Lead-212	pCi/g	0.5864	0.5864	0.5864	1
Lead-214	pCi/g	1.393	1.393	1.393	1
Mercury	mg/kg	0.29	0.29	0.29	1
Neptunium-237	pCi/g	0.7628	0.77	0.7664	2
PCB-1254	ug/kg	400	400	400	1
PCB-1260	ug/kg	300	300	300	1
Plutonium-238	pCi/g	0.22	0.258	0.239	2
Plutonium-239/240	pCi/g	7.8	14	10.9	2
Polychlorinated biphenyl	ug/kg	700	700	700	1
Potassium-40	pCi/g	6.264	6.264	6.264	1
Protactinium-234m	pCi/g	46.62	46.62	46.62	1
Radium-223	pCi/g	0.7357	0.7357	0.7357	1
Technetium-99	pCi/g	114	114	114	1
Thorium-228	pCi/g	0.4027	0.936	0.66935	2
Thorium-230	pCi/g	69.9	69.9	69.9	1
Thorium-232	pCi/g	0.427	1.06	0.7435	2
Uranium	mg/kg	168	168	168	1
Uranium	pCi/g	86.4	86.4	86.4	1
Uranium-234	pCi/g	30.5	33	31.75	2
Uranium-235	pCi/g	1.6	1.6	1.6	1
Uranium-235	wt %	0.5	0.5	0.5	1
Uranium-238	pCi/g	54.2	56	55.1	2

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Table C.74 Sediment at JP-0081

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.4242	0.4242	0.4242	1
Alpha activity	pCi/g	7.35	7.35	7.35	1
Americium-241	pCi/g	0.1102	0.1102	0.1102	1
Beryllium	mg/kg	1.38	1.38	1.38	1
Beta activity	pCi/g	13.94	13.94	13.94	1
Bismuth-212	pCi/g	0.6308	0.6308	0.6308	1
Bismuth-214	pCi/g	0.6029	0.6029	0.6029	1
Cesium-137	pCi/g	0.1152	0.1152	0.1152	1
Chromium	mg/kg	23.8	23.8	23.8	1
Lead-212	pCi/g	0.4161	0.4161	0.4161	1
Lead-214	pCi/g	0.6405	0.6405	0.6405	1
Neptunium-237	pCi/g	0.05	0.05	0.05	1
Plutonium-239/240	pCi/g	0.029	0.757	0.393	2
Potassium-40	pCi/g	3.506	3.506	3.506	1
Protactinium-231	pCi/g	0.2558	0.2558	0.2558	1
Protactinium-233	pCi/g	0.1225	0.1225	0.1225	1
Protactinium-234m	pCi/g	2.734	2.734	2.734	1
Technetium-99	pCi/g	9.81	9.81	9.81	1
Thorium-228	pCi/g	0.426	0.426	0.426	1
Thorium-230	pCi/g	11.6	11.6	11.6	1
Thorium-232	pCi/g	0.2091	0.426	0.31755	2
Uranium	mg/kg	11	11	11	1
Uranium	pCi/g	5.21	5.21	5.21	1
Uranium-234	pCi/g	2.13	2.6	2.365	2
Uranium-235	pCi/g	0.11	0.11	0.11	1
Uranium-235	wt %	0.59	0.59	0.59	1
Uranium-238	pCi/g	2.96	3.6	3.28	2

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Table C.75 Sediment at JP-0082

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.8681	0.8681	0.8681	1
Alpha activity	pCi/g	85.5	85.5	85.5	1
Americium-241	pCi/g	1.382	1.382	1.382	1
Beryllium	mg/kg	0.68	0.68	0.68	1
Beta activity	pCi/g	125.69	125.69	125.69	1
Bismuth-212	pCi/g	0.811	0.811	0.811	1
Bismuth-214	pCi/g	1.269	1.269	1.269	1
Cesium-137	pCi/g	1.226	1.226	1.226	1
Chromium	mg/kg	60.6	60.6	60.6	1
Lead-212	pCi/g	0.7561	0.7561	0.7561	1
Lead-214	pCi/g	1.311	1.311	1.311	1
Neptunium-237	pCi/g	0.86	0.9226	0.8913	2
PCB-1254	ug/kg	100	100	100	1
PCB-1260	ug/kg	100	100	100	1
Plutonium-238	pCi/g	0.089	0.089	0.089	1
Plutonium-239/240	pCi/g	3.05	4.1	3.575	2
Polychlorinated biphenyl	ug/kg	200	200	200	1
Potassium-40	pCi/g	9.93	9.93	9.93	1
Protactinium-234m	pCi/g	17.73	17.73	17.73	1
Radium-223	pCi/g	0.3809	0.3809	0.3809	1
Technetium-99	pCi/g	72.4	72.4	72.4	1
Thorium-228	pCi/g	0.741	0.741	0.741	1
Thorium-230	pCi/g	47.1	47.1	47.1	1
Thorium-232	pCi/g	0.4708	0.808	0.6394	2
Uranium	mg/kg	61	61	61	1
Uranium	pCi/g	35.5	35.5	35.5	1
Uranium-234	pCi/g	14	14.9	14.45	2
Uranium-235	pCi/g	0.74	0.74	0.74	1
Uranium-235	wt %	0.61	0.61	0.61	1
Uranium-238	pCi/g	19.9	20	19.95	2

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Table C.76 Sediment at JP-0087

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.6444	0.8659	0.75515	2
Alpha activity	pCi/g	245.78	245.78	245.78	1
Beta activity	pCi/g	346.48	346.48	346.48	1
Bismuth-212	pCi/g	0.6731	0.7914	0.73225	2
Bismuth-214	pCi/g	0.7236	0.732	0.7278	2
Cesium-137	pCi/g	0.07685	0.08359	0.08022	2
Chromium	mg/kg	19.2	19.8	19.5	2
Lead-212	pCi/g	0.4054	0.828	0.6167	2
Lead-214	pCi/g	0.6772	0.784	0.7306	2
PCB-1254	ug/kg	600	600	600	1
PCB-1260	ug/kg	500	700	600	2
Polychlorinated biphenyl	ug/kg	700	1100	900	2
Potassium-40	pCi/g	9.499	9.84	9.6695	2
Protactinium-234m	pCi/g	114.3	127.3	120.8	2
Thallium-208	pCi/g	0.3096	0.3096	0.3096	1
Thorium-228	pCi/g	0.495	0.552	0.5235	2
Thorium-230	pCi/g	0.352	0.359	0.3555	2
Thorium-232	pCi/g	0.2739	0.528	0.4180	3
Uranium	mg/kg	364	377	370.5	2
Uranium	pCi/g	138	150	144	2
Uranium-234	pCi/g	10.3	13	11.825	4
Uranium-235	pCi/g	1.3	1.8	1.55	2
Uranium-235	wt %	0.19	0.19	0.19	2
Uranium-238	pCi/g	122	138	128.25	4

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Table C.77 Sediment at JP-0091

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.9794	0.9794	0.9794	1
Alpha activity	pCi/g	35.42	35.42	35.42	1
Beta activity	pCi/g	31.7	31.7	31.7	1
Bismuth-212	pCi/g	0.8068	0.8068	0.8068	1
Bismuth-214	pCi/g	0.9238	0.9238	0.9238	1
Chromium	mg/kg	8.43	8.43	8.43	1
Lead-212	pCi/g	0.7682	0.7682	0.7682	1
Lead-214	pCi/g	0.8645	0.8645	0.8645	1
PCB-1254	ug/kg	100	100	100	1
PCB-1260	ug/kg	200	200	200	1
Polychlorinated biphenyl	ug/kg	300	300	300	1
Potassium-40	pCi/g	2.68	2.68	2.68	1
Protactinium-234m	pCi/g	11.43	11.43	11.43	1
Thallium-208	pCi/g	0.234	0.234	0.234	1
Thorium-228	pCi/g	0.368	0.368	0.368	1
Thorium-230	pCi/g	0.24	0.24	0.24	1
Thorium-232	pCi/g	0.1604	0.176	0.1682	2
Uranium	mg/kg	11	11	11	1
Uranium	pCi/g	14.5	14.5	14.5	1
Uranium-234	pCi/g	1.2	1.69	1.445	2
Uranium-235	pCi/g	0.062	0.062	0.062	1
Uranium-235	wt %	0.23	0.23	0.23	1
Uranium-238	pCi/g	3.9	12.7	8.3	2

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Table C.78 Sediment at JP-0092

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	4300.73	4300.73	4300.73	1
Beryllium	mg/kg	1.33	1.33	1.33	1
Beta activity	pCi/g	7711.33	7711.33	7711.33	1
Bismuth-214	pCi/g	1.038	1.038	1.038	1
Cesium-137	pCi/g	1.172	1.172	1.172	1
Chromium	mg/kg	175	175	175	1
Lead-212	pCi/g	0.7156	0.7156	0.7156	1
Lead-214	pCi/g	0.9276	0.9276	0.9276	1
Neptunium-237	pCi/g	0.061	0.061	0.061	1
PCB-1242	ug/kg	28000	28000	28000	1
PCB-1254	ug/kg	24000	24000	24000	1
PCB-1260	ug/kg	27000	27000	27000	1
Plutonium-239/240	pCi/g	0.0594	0.098	0.0787	2
Polychlorinated biphenyl	ug/kg	79000	79000	79000	1
Potassium-40	pCi/g	10.11	10.11	10.11	1
Protactinium-231	pCi/g	36.47	36.47	36.47	1
Protactinium-234m	pCi/g	4383	4383	4383	1
Radium-228	pCi/g	0.9619	0.9619	0.9619	1
Strontium-90	pCi/g	4.7	4.7	4.7	1
Technetium-99	pCi/g	7.64	7.64	7.64	1
Thallium-208	pCi/g	0.222	0.222	0.222	1
Thorium-228	pCi/g	0.392	0.392	0.392	1
Thorium-230	pCi/g	1.15	1.15	1.15	1
Thorium-232	pCi/g	0.482	0.482	0.482	1
Uranium	mg/kg	13070	13070	13070	1
Uranium	pCi/g	3680	3680	3680	1
Uranium-234	pCi/g	267	445	356	2
Uranium-235	pCi/g	57	57	57	1
Uranium-235	wt %	0.19	0.19	0.19	1
Uranium-238	pCi/g	3370	4386	3878	2

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Table C.79 Sediment at JP-0097

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.912	0.912	0.912	1
Alpha activity	pCi/g	11.41	11.41	11.41	1
Beta activity	pCi/g	7.12	7.12	7.12	1
Bismuth-212	pCi/g	0.6239	0.6239	0.6239	1
Bismuth-214	pCi/g	0.7933	0.7933	0.7933	1
Cesium-137	pCi/g	0.1997	0.1997	0.1997	1
Chromium	mg/kg	28	28	28	1
Lead-212	pCi/g	0.8369	0.8369	0.8369	1
Lead-214	pCi/g	0.7746	0.7746	0.7746	1
Potassium-40	pCi/g	11.23	11.23	11.23	1
Protactinium-231	pCi/g	0.5667	0.5667	0.5667	1
Protactinium-234m	pCi/g	2.47	2.47	2.47	1
Thallium-208	pCi/g	0.345	0.345	0.345	1
Thorium-228	pCi/g	0.532	0.532	0.532	1
Thorium-230	pCi/g	0.516	0.516	0.516	1
Thorium-232	pCi/g	0.51	0.51	0.51	1
Uranium	mg/kg	6.8	6.8	6.8	1
Uranium-234	pCi/g	1	1	1	1
Uranium-235	pCi/g	0.047	0.047	0.047	1
Uranium-235	wt %	0.47	0.47	0.47	1
Uranium-238	pCi/g	2.3	2.3	2.3	1

Table C.80 Sediment at JP-0100

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.5961	0.5961	0.5961	1
Alpha activity	pCi/g	13.59	13.59	13.59	1
Beryllium	mg/kg	0.59	0.59	0.59	1
Bismuth-212	pCi/g	0.5843	0.5843	0.5843	1
Bismuth-214	pCi/g	0.7382	0.7382	0.7382	1
Cesium-137	pCi/g	0.07769	0.07769	0.07769	1
Chromium	mg/kg	17.6	17.6	17.6	1
Lead-212	pCi/g	0.5678	0.5678	0.5678	1
Lead-214	pCi/g	0.7896	0.7896	0.7896	1
Potassium-40	pCi/g	10.92	10.92	10.92	1
Protactinium-231	pCi/g	0.4058	0.4058	0.4058	1
Thorium-228	pCi/g	0.638	0.638	0.638	1
Thorium-230	pCi/g	0.775	0.775	0.775	1
Thorium-232	pCi/g	0.3538	0.619	0.4864	2
Uranium	mg/kg	2.6	2.6	2.6	1
Uranium-234	pCi/g	0.68	0.68	0.68	1
Uranium-235	pCi/g	0.034	0.034	0.034	1
Uranium-235	wt %	0.69	0.69	0.69	1
Uranium-238	pCi/g	0.86	0.86	0.86	1

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Table C.81 Sediment at JP-0110

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	865.14	865.14	865.14	1
Beryllium	mg/kg	0.57	0.57	0.57	1
Beta activity	pCi/g	1282.19	1282.19	1282.19	1
Bismuth-214	pCi/g	0.8686	0.8686	0.8686	1
Cesium-137	pCi/g	0.129	0.129	0.129	1
Chromium	mg/kg	324	324	324	1
Lead-212	pCi/g	0.6913	0.6913	0.6913	1
Lead-214	pCi/g	0.9106	0.9106	0.9106	1
PCB-1248	ug/kg	13000	13000	13000	1
PCB-1254	ug/kg	4700	4700	4700	1
PCB-1260	ug/kg	2600	2600	2600	1
Polychlorinated biphenyl	ug/kg	20300	20300	20300	1
Potassium-40	pCi/g	8.274	8.274	8.274	1
Protactinium-234m	pCi/g	721	721	721	1
Radium-228	pCi/g	0.7073	0.7073	0.7073	1
Thorium-228	pCi/g	0.493	0.493	0.493	1
Thorium-230	pCi/g	0.456	0.456	0.456	1
Thorium-232	pCi/g	0.3392	0.421	0.3801	2
Uranium	mg/kg	1132	1132	1132	1
Uranium	pCi/g	672	672	672	1
Uranium-234	pCi/g	34	39	36.5	2
Uranium-235	pCi/g	5.6	5.6	5.6	1
Uranium-235	wt %	0.18	0.18	0.18	1
Uranium-238	pCi/g	380	626	503	2

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Table C.82 Sediment at JP-0111

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.8861	1.047	0.96655	2
Alpha activity	pCi/g	325.19	325.19	325.19	1
Beryllium	mg/kg	0.58	0.58	0.58	1
Beta activity	pCi/g	732.47	732.47	732.47	1
Bismuth-212	pCi/g	0.9931	1.288	1.14055	2
Bismuth-214	pCi/g	0.8871	0.8977	0.8924	2
Cesium-137	pCi/g	0.1828	0.2329	0.20785	2
Chromium	mg/kg	209	214	211.5	2
Lead-212	pCi/g	0.6706	1.004	0.8373	2
Lead-214	pCi/g	0.8615	0.8957	0.8786	2
PCB-1254	ug/kg	600	600	600	1
PCB-1260	ug/kg	600	700	650	2
Polychlorinated biphenyl	ug/kg	600	1300	950	2
Potassium-40	pCi/g	8.645	9.446	9.0455	2
Protactinium-234m	pCi/g	329.9	331.2	330.55	2
Radium-223	pCi/g	0.4047	0.4047	0.4047	1
Thallium-208	pCi/g	0.3277	0.3277	0.3277	1
Thorium-228	pCi/g	0.378	0.459	0.4185	2
Thorium-230	pCi/g	0.373	0.412	0.3925	2
Thorium-232	pCi/g	0.382	0.396	0.3840	3
Uranium	mg/kg	944	1086	1015	2
Uranium	pCi/g	334	334	334	2
Uranium-234	pCi/g	23.6	40	29.775	4
Uranium-235	pCi/g	3.5	4.4	3.95	2
Uranium-235	wt %	0.19	0.19	0.19	2
Uranium-238	pCi/g	306	365	323.5	4

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Table C.83 Sediment at JP-0112

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.3357	0.3357	0.3357	1
Alpha activity	pCi/g	9.53	9.53	9.53	1
Beryllium	mg/kg	3.27	3.27	3.27	1
Beta activity	pCi/g	15.23	15.23	15.23	1
Bismuth-212	pCi/g	0.4171	0.4171	0.4171	1
Bismuth-214	pCi/g	0.6953	0.6953	0.6953	1
Cesium-137	pCi/g	0.02672	0.02672	0.02672	1
Chromium	mg/kg	346	346	346	1
Lead-212	pCi/g	0.2848	0.2848	0.2848	1
Lead-214	pCi/g	0.7265	0.7265	0.7265	1
Potassium-40	pCi/g	1.725	1.725	1.725	1
Protactinium-234m	pCi/g	6.174	6.174	6.174	1
Thorium-228	pCi/g	0.325	0.325	0.325	1
Thorium-230	pCi/g	0.473	0.473	0.473	1
Thorium-232	pCi/g	0.1905	0.343	0.26675	2
Uranium	mg/kg	22	22	22	1
Uranium	pCi/g	8.47	8.47	8.47	1
Uranium-234	pCi/g	1.5	1.62	1.56	2
Uranium-235	pCi/g	0.13	0.13	0.13	1
Uranium-235	wt %	0.3	0.3	0.3	1
Uranium-238	pCi/g	6.72	7.5	7.11	2

Table C.84 Sediment at P-0113

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.7344	0.7344	0.7344	1
Alpha activity	pCi/g	10.1	10.1	10.1	1
Beta activity	pCi/g	14.45	14.45	14.45	1
Bismuth-212	pCi/g	0.6372	0.6372	0.6372	1
Bismuth-214	pCi/g	0.5832	0.5832	0.5832	1
Cesium-137	pCi/g	0.04143	0.04143	0.04143	1
Chromium	mg/kg	31.9	31.9	31.9	1
Lead-212	pCi/g	0.6313	0.6313	0.6313	1
Lead-214	pCi/g	0.5611	0.5611	0.5611	1
Potassium-40	pCi/g	5.174	5.174	5.174	1
Protactinium-231	pCi/g	0.4431	0.4431	0.4431	1
Protactinium-234m	pCi/g	5.694	5.694	5.694	1
Thallium-208	pCi/g	0.2537	0.2537	0.2537	1
Thorium-228	pCi/g	0.227	0.227	0.227	1
Thorium-230	pCi/g	0.195	0.195	0.195	1
Thorium-232	pCi/g	0.254	0.254	0.254	1
Uranium	mg/kg	16	16	16	1
Uranium	pCi/g	7.16	7.16	7.16	1
Uranium-234	pCi/g	0.99	1.04	1.015	2
Uranium-235	pCi/g	0.07	0.07	0.07	1
Uranium-235	wt %	0.25	0.25	0.25	1
Uranium-238	pCi/g	5.3	6.02	5.66	2

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Table C.85 Sediment at JP-0164

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.6703	0.6703	0.6703	1
Alpha activity	pCi/g	8.35	8.35	8.35	1
Beryllium	mg/kg	0.6	0.6	0.6	1
Bismuth-212	pCi/g	0.6869	0.6869	0.6869	1
Bismuth-214	pCi/g	0.8037	0.8037	0.8037	1
Cesium-137	pCi/g	0.1796	0.1796	0.1796	1
Chromium	mg/kg	16.1	16.1	16.1	1
Lead-212	pCi/g	0.5937	0.5937	0.5937	1
Lead-214	pCi/g	0.7692	0.7692	0.7692	1
Potassium-40	pCi/g	12.11	12.11	12.11	1
Protactinium-231	pCi/g	0.5757	0.5757	0.5757	1
Protactinium-234m	pCi/g	1.534	1.534	1.534	1
Radium-223	pCi/g	0.09755	0.09755	0.09755	1
Thorium-228	pCi/g	0.617	0.617	0.617	1
Thorium-230	pCi/g	0.573	0.573	0.573	1
Thorium-232	pCi/g	0.3432	0.573	0.4581	2
Uranium	mg/kg	1.7	1.7	1.7	1
Uranium-234	pCi/g	0.41	0.41	0.41	1
Uranium-235	wt %	0.61	0.61	0.61	1
Uranium-238	pCi/g	0.57	0.57	0.57	1

OUTFALLS

Table C.86 Surface Water Data at Outfall K011

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	97.11	124.87	110.895	4
Beta activity	pCi/g	173.2	190.43	182.7475	4
Cesium-137	pCi/g	0.114	0.158	0.136	2
PCB-1248	ug/kg	1400	1600	1500	2
PCB-1254	ug/kg	1400	1700	1550	2
PCB-1260	ug/kg	1800	2000	1900	2
Plutonium-239/240	pCi/g	0.0109	0.0109	0.0109	1
Polychlorinated biphenyl	ug/kg	4600	5300	4950	2
Technetium-99	pCi/g	0.917	1.53	1.2235	2
Thorium-230	pCi/g	0.495	0.509	0.502	2
Uranium	pCi/g	98.8	109	103.9	2
Uranium-235	wt %	0.2	0.21	0.205	2

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Table C.87 Surface Water Data at Outfall K015

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	195.1	200.87	197.985	2
Americium-241	pCi/g	2.28	2.28	2.28	1
Beta activity	pCi/g	222.45	223.1	222.775	2
Cesium-137	pCi/g	52.3	52.3	52.3	1
Plutonium-239/240	pCi/g	18.4	18.4	18.4	1
Technetium-99	pCi/g	17.9	17.9	17.9	1
Thorium-230	pCi/g	22	22	22	1
Uranium	pCi/g	108	108	108	1
Uranium-235	wt %	0.39	0.39	0.39	1

Table C.88 Surface Water Data at Outfall K017

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	10.18	16.38	13.28	2
Beta activity	pCi/g	6.69	7.49	7.09	2
Plutonium-239/240	pCi/g	0.0244	0.0244	0.0244	1
Technetium-99	pCi/g	0.373	0.373	0.373	1
Thorium-230	pCi/g	0.684	0.684	0.684	1
Uranium	pCi/g	3.87	3.87	3.87	1

Table C.89 Surface Water Data at Location L303

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	3.67	3.88	3.775	2
Aluminum	mg/kg	7180	7380	7280	2
Barium	mg/kg	44.8	49	46.9	2
Beta activity	pCi/L	8.1	8.1	8.1	1
Beta activity	pCi/g	3.51	3.56	3.535	2
Calcium	mg/kg	765	796	780.5	2
Chromium	mg/kg	10.3	12.1	11.2	2
Cobalt	mg/kg	3.99	4.34	4.165	2
Copper	mg/kg	7.19	7.89	7.54	2
Iron	mg/kg	9740	10100	9920	2
Magnesium	mg/kg	974	981	977.5	2
Manganese	mg/kg	189	226	207.5	2
Nickel	mg/kg	7.18	7.19	7.185	2
pH	none	7.25	7.31	7.28	2
Potassium	mg/kg	465	552	508.5	2
Technetium-99	pCi/g	0.407	0.407	0.407	1
Thorium-230	pCi/g	2.48	4.17	3.325	2
Uranium	pCi/g	1.18	1.18	1.18	1
Vanadium	mg/kg	17.1	17.4	17.25	2
Zinc	mg/kg	26.9	28.6	27.75	2
Iron	mg/L	0.889	1.44	1.1645	2

DOJ Special Investigations Data

Railcar

Table C.90 Waste Sample in Abandoned Railcar

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	8.99	8.99	8.99	1
Beta activity	pCi/g	14.8	14.8	14.8	1
Tritium	pCi/g	7.08	15.57	11.325	2
Alpha activity	pCi/ml	108.36	108.36	108.36	1
Beta activity	pCi/ml	60.84	60.84	60.84	1
Tritium	pCi/L	1096.85	1189.64	1143.245	2

Soil

Table C.91 Soil Data at Location JP-0060

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	22.93	22.93	22.93	1
Beta activity	pCi/g	35.14	35.14	35.14	1
Cesium-137	pCi/g	0.0471	0.0471	0.0471	1
Chromium	mg/kg	15.2	15.2	15.2	1
Lead-212	pCi/g	0.09822	0.09822	0.09822	1
Mercury	mg/kg	0.98	0.98	0.98	1
Neptunium-237	pCi/g	0.053	0.0912	0.0721	2
Plutonium-239/240	pCi/g	0.0672	0.0672	0.0672	1
Potassium-40	pCi/g	1.06	1.06	1.06	1
Protactinium-231	pCi/g	0.1972	0.1972	0.1972	1
Protactinium-234m	pCi/g	6.87	6.87	6.87	1
Technetium-99	pCi/g	8.17	8.17	8.17	1
Thorium-230	pCi/g	1.02	1.02	1.02	1
Uranium	mg/kg	20	20	20	1
Uranium	pCi/g	14.3	14.3	14.3	1
Uranium-234	pCi/g	5	5.7	5.35	2
Uranium-235	pCi/g	0.27	0.27	0.27	1
Uranium-235	wt %	0.58	0.58	0.58	1
Uranium-238	pCi/g	6.7	8.24	7.47	2

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Table C.92 Soil Data at Location JP-0075

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	1.414	1.414	1.414	1
Alpha activity	pCi/g	109.29	109.29	109.29	1
Americium-241	pCi/g	1.19	1.19	1.19	1
Beryllium	mg/kg	0.77	0.77	0.77	1
Beta activity	pCi/g	82.98	82.98	82.98	1
Bismuth-212	pCi/g	0.8676	0.8676	0.8676	1
Bismuth-214	pCi/g	0.6198	0.6198	0.6198	1
Cesium-137	pCi/g	0.76	0.76	0.76	1
Chromium	mg/kg	48.4	48.4	48.4	1
Lead-212	pCi/g	1.32	1.32	1.32	1
Lead-214	pCi/g	0.7156	0.7156	0.7156	1
Neptunium-237	pCi/g	0.29	0.29	0.29	1
Plutonium-238	pCi/g	0.062	0.062	0.062	1
Plutonium-239/240	pCi/g	2.28	2.9	2.59	2
Potassium-40	pCi/g	8.84	8.84	8.84	1
Protactinium-231	pCi/g	0.6977	0.6977	0.6977	1
Protactinium-234m	pCi/g	12.8	12.8	12.8	1
Technetium-99	pCi/g	98.1	98.1	98.1	1
Thallium-208	pCi/g	0.4175	0.4175	0.4175	1
Thorium-228	pCi/g	0.717	0.717	0.717	1
Thorium-230	pCi/g	25.7	34.8	30.25	2
Thorium-232	pCi/g	0.582	0.582	0.582	1
Thorium-234	pCi/g	12.8	12.8	12.8	1
Uranium	mg/kg	43	43	43	1
Uranium	pCi/g	24.1	24.1	24.1	1
Uranium-234	pCi/g	8.77	9.3	9.035	2
Uranium-235	pCi/g	0.35	0.35	0.35	1
Uranium-235	wt %	0.52	0.52	0.52	1
Uranium-238	pCi/g	14	14.8	14.4	2

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Table C.93 Soil Data at Location JP-0076

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	1.51	1.51	1.51	1
Alpha activity	pCi/g	346.56	346.56	346.56	1
Americium-241	pCi/g	4.386	4.386	4.386	1
Beta activity	pCi/g	308.08	308.08	308.08	1
Bismuth-212	pCi/g	1.259	1.259	1.259	1
Bismuth-214	pCi/g	2.068	2.068	2.068	1
Cesium-137	pCi/g	2.943	2.943	2.943	1
Chromium	mg/kg	268	268	268	1
Lead-212	pCi/g	1.33	1.33	1.33	1
Lead-214	pCi/g	2.207	2.207	2.207	1
Mercury	mg/kg	0.4	0.4	0.4	1
Neodymium-147	pCi/g	0.882	0.882	0.882	1
Neptunium-237	pCi/g	1.34	1.8	1.57	2
PCB-1254	ug/kg	400	400	400	1
PCB-1260	ug/kg	400	400	400	1
Plutonium-238	pCi/g	0.233	0.41	0.3215	2
Plutonium-239/240	pCi/g	8.84	14	11.42	2
Polychlorinated biphenyl	ug/kg	800	800	800	1
Potassium-40	pCi/g	8.533	8.533	8.533	1
Protactinium-234m	pCi/g	58.54	58.54	58.54	1
Technetium-99	pCi/g	177	177	177	1
Thorium-228	pCi/g	1.43	1.43	1.43	1
Thorium-230	pCi/g	104	104	104	1
Thorium-232	pCi/g	0.7228	1.49	1.1064	2
Uranium	mg/kg	190	190	190	1
Uranium	pCi/g	115	115	115	1
Uranium-234	pCi/g	43	43.7	43.35	2
Uranium-235	pCi/g	2.4	2.4	2.4	1
Uranium-235	wt %	0.54	0.54	0.54	1
Uranium-238	pCi/g	63	69	66	2

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Table C.94 Soil Data at Location JP-0080

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	1.031	1.031	1.031	1
Alpha activity	pCi/g	9.44	9.44	9.44	1
Beryllium	mg/kg	0.68	0.68	0.68	1
Beta activity	pCi/g	18.32	18.32	18.32	1
Bismuth-212	pCi/g	0.6683	0.6683	0.6683	1
Bismuth-214	pCi/g	0.9013	0.9013	0.9013	1
Cesium-137	pCi/g	0.06943	0.06943	0.06943	1
Chromium	mg/kg	13	13	13	1
Lead-212	pCi/g	0.9453	0.9453	0.9453	1
Lead-214	pCi/g	0.8814	0.8814	0.8814	1
Neptunium-237	pCi/g	0.031	0.031	0.031	1
Plutonium-239/240	pCi/g	0.157	0.17	0.1635	2
Potassium-40	pCi/g	7.491	7.491	7.491	1
Protactinium-231	pCi/g	0.5172	0.5172	0.5172	1
Protactinium-234m	pCi/g	1.973	1.973	1.973	1
Technetium-99	pCi/g	15.4	15.4	15.4	1
Thallium-208	pCi/g	0.3785	0.3785	0.3785	1
Thorium-228	pCi/g	0.353	0.353	0.353	1
Thorium-230	pCi/g	2.98	2.98	2.98	1
Thorium-232	pCi/g	0.376	0.376	0.376	1
Uranium	mg/kg	4.9	4.9	4.9	1
Uranium-234	pCi/g	1.3	1.3	1.3	1
Uranium-235	pCi/g	0.054	0.054	0.054	1
Uranium-235	wt %	0.64	0.64	0.64	1
Uranium-238	pCi/g	1.6	1.6	1.6	1

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Table C.95 Soil Data at Location JP-0085

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.6512	0.6512	0.6512	1
Alpha activity	pCi/g	248.73	248.73	248.73	1
Beta activity	pCi/g	303.75	303.75	303.75	1
Bismuth-212	pCi/g	0.7838	0.7838	0.7838	1
Bismuth-214	pCi/g	0.6878	0.6878	0.6878	1
Cesium-137	pCi/g	0.1484	0.1484	0.1484	1
Chromium	mg/kg	77.7	77.7	77.7	1
Lead-212	pCi/g	0.5794	0.5794	0.5794	1
Lead-214	pCi/g	0.8056	0.8056	0.8056	1
Neptunium-237	pCi/g	0.12	0.12	0.12	1
PCB-1254	ug/kg	500	500	500	1
PCB-1260	ug/kg	1300	1300	1300	1
Plutonium-239/240	pCi/g	0.036	0.036	0.036	1
Polychlorinated biphenyl	ug/kg	1800	1800	1800	1
Potassium-40	pCi/g	10.05	10.05	10.05	1
Thorium-228	pCi/g	0.479	0.479	0.479	1
Thorium-230	pCi/g	0.345	0.345	0.345	1
Thorium-232	pCi/g	0.2832	0.379	0.3311	2
Uranium	mg/kg	346	346	346	1
Uranium	pCi/g	177	177	177	1
Uranium-234	pCi/g	14	14.3	14.15	2
Uranium-235	pCi/g	1.7	1.7	1.7	1
Uranium-235	wt %	0.2	0.2	0.2	1
Uranium-238	pCi/g	116	160	138	2

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Table C.96 Soil Data at Location JP-0090

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.842	0.842	0.842	1
Alpha activity	pCi/g	29.41	29.41	29.41	1
Beryllium	mg/kg	0.68	0.68	0.68	1
Beta activity	pCi/g	40	40	40	1
Bismuth-212	pCi/g	0.8128	0.8128	0.8128	1
Bismuth-214	pCi/g	0.7387	0.7387	0.7387	1
Cesium-137	pCi/g	0.1042	0.1042	0.1042	1
Chromium	mg/kg	18	18	18	1
Lead-212	pCi/g	0.735	0.735	0.735	1
Lead-214	pCi/g	0.8322	0.8322	0.8322	1
PCB-1260	ug/kg	100	100	100	1
Polychlorinated biphenyl	ug/kg	100	100	100	1
Potassium-40	pCi/g	11.25	11.25	11.25	1
Protactinium-234m	pCi/g	18.72	18.72	18.72	1
Thallium-208	pCi/g	0.2451	0.2451	0.2451	1
Thorium-228	pCi/g	0.443	0.443	0.443	1
Thorium-230	pCi/g	0.37	0.37	0.37	1
Thorium-232	pCi/g	0.515	0.515	0.515	1
Uranium	mg/kg	64	64	64	1
Uranium	pCi/g	23.1	23.1	23.1	1
Uranium-234	pCi/g	2.14	2.8	2.47	2
Uranium-235	pCi/g	0.24	0.372	0.306	2
Uranium-235	wt %	0.21	0.21	0.21	1
Uranium-238	pCi/g	20.7	22	21.35	2

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Table C.97 Soil Data at Location JP-0150

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.9663	0.9663	0.9663	1
Alpha activity	pCi/g	632.07	632.07	632.07	1
Beryllium	mg/kg	0.59	0.59	0.59	1
Beta activity	pCi/g	936.59	936.59	936.59	1
Bismuth-212	pCi/g	0.8214	0.8214	0.8214	1
Bismuth-214	pCi/g	0.6941	0.6941	0.6941	1
Cesium-137	pCi/g	0.0906	0.0906	0.0906	1
Chromium	mg/kg	55.8	55.8	55.8	1
Lead-212	pCi/g	0.6114	0.6114	0.6114	1
Lead-214	pCi/g	0.791	0.791	0.791	1
Neptunium-237	pCi/g	0.338	0.338	0.338	1
Plutonium-239/240	pCi/g	0.044	0.044	0.044	1
Potassium-40	pCi/g	10.6	10.6	10.6	1
Protactinium-234m	pCi/g	596	596	596	1
Technetium-99	pCi/g	13.8	13.8	13.8	1
Thallium-208	pCi/g	0.2787	0.2787	0.2787	1
Thorium-228	pCi/g	0.452	0.452	0.452	1
Thorium-230	pCi/g	0.716	0.716	0.716	1
Thorium-232	pCi/g	0.271	0.271	0.271	1
Uranium	mg/kg	1170	1170	1170	1
Uranium	pCi/g	721	721	721	1
Uranium-234	pCi/g	86	112	99	2
Uranium-235	pCi/g	4.8	4.8	4.8	1
Uranium-235	wt %	0.26	0.26	0.26	1
Uranium-238	pCi/g	393	599	496	2

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Table C.98 Soil Data at Location JP-0151

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.4963	0.4963	0.4963	1
Alpha activity	pCi/g	417.53	417.53	417.53	1
Beryllium	mg/kg	0.56	0.56	0.56	1
Beta activity	pCi/g	866.99	866.99	866.99	1
Bismuth-214	pCi/g	0.5999	0.5999	0.5999	1
Cesium-137	pCi/g	0.393	0.393	0.393	1
Chromium	mg/kg	15.5	15.5	15.5	1
Lead-212	pCi/g	0.3821	0.3821	0.3821	1
Lead-214	pCi/g	0.5734	0.5734	0.5734	1
PCB-1254	ug/kg	1100	1100	1100	1
Polychlorinated biphenyl	ug/kg	1100	1100	1100	1
Potassium-40	pCi/g	6.56	6.56	6.56	1
Thallium-208	pCi/g	0.1811	0.1811	0.1811	1
Thorium-228	pCi/g	0.257	0.257	0.257	1
Thorium-230	pCi/g	0.385	0.385	0.385	1
Thorium-232	pCi/g	0.23	0.23	0.23	1
Uranium	mg/kg	943	943	943	1
Uranium	pCi/g	388	388	388	1
Uranium-234	pCi/g	19.2	27	23.1	2
Uranium-235	pCi/g	3.1	3.1	3.1	1
Uranium-235	wt %	0.17	0.17	0.17	1
Uranium-238	pCi/g	317	365	341	2

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Table C.99 Soil Data at Location JP-0152

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.2618	0.2618	0.2618	1
Alpha activity	pCi/g	72.42	72.42	72.42	1
Americium-241	pCi/g	1.29	2.93	2.11	2
Beta activity	pCi/g	838.61	838.61	838.61	1
Bismuth-214	pCi/g	0.6873	0.6946	0.69095	2
Cesium-137	pCi/g	0.355	0.365	0.36	2
Chromium	mg/kg	163	231	197	2
Lead-212	pCi/g	0.1848	0.2477	0.21625	2
Lead-214	pCi/g	0.7312	0.7833	0.75725	2
Mercury	mg/kg	7.84	12.4	10.12	2
Neptunium-237	pCi/g	1.7	3.31	2.5975	4
PCB-1254	ug/kg	300	300	300	1
PCB-1260	ug/kg	1500	1600	1550	2
Plutonium-238	pCi/g	0.067	0.386	0.25467	3
Plutonium-239/240	pCi/g	1.8	7.2	4.415	4
Polychlorinated biphenyl	ug/kg	1500	1900	1700	2
Potassium-40	pCi/g	2.11	2.26	2.185	2
Protactinium-233	pCi/g	0.5592	1.064	0.8116	2
Protactinium-234m	pCi/g	169	182	175.5	2
Radium-223	pCi/g	0.5486	0.6287	0.58865	2
Radium-228	pCi/g	0.1482	0.1482	0.1482	1
Radon-219	pCi/g	0.3372	0.3372	0.3372	1
Strontium-90	pCi/g	3.6	7	5.3	2
Technetium-99	pCi/g	1650	1870	1760	2
Thorium-227	pCi/g	0.2894	0.2894	0.2894	1
Thorium-228	pCi/g	0.314	0.374	0.344	2
Thorium-230	pCi/g	26.7	29.2	27.95	2
Thorium-232	pCi/g	0.09141	0.346	0.2097625	4
Uranium	mg/kg	621	1173	897	2
Uranium	pCi/g	258	278	268	2
Uranium-234	pCi/g	71	139	92.975	4
Uranium-235	pCi/g	4.7	8.8	6.75	2
Uranium-235	wt %	0.42	0.43	0.425	2
Uranium-238	pCi/g	175	393	241.5	4

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Table C.100 Soil Data at Location JP-0153

Analysis	Units	Minimum	Maximum	Average	Detected Count
Alpha activity	pCi/g	942.53	942.53	942.53	1
Beryllium	mg/kg	0.78	0.78	0.78	1
Beta activity	pCi/g	4337.65	4337.65	4337.65	1
Bismuth-214	pCi/g	0.633	0.633	0.633	1
Cesium-137	pCi/g	0.271	0.271	0.271	1
Chromium	mg/kg	165	165	165	1
Lead-212	pCi/g	0.1997	0.1997	0.1997	1
Lead-214	pCi/g	0.4105	0.4105	0.4105	1
Mercury	mg/kg	0.45	0.45	0.45	1
Neptunium-237	pCi/g	0.18	0.505	0.3425	2
PCB-1254	ug/kg	6300	6300	6300	1
PCB-1260	ug/kg	2800	2800	2800	1
Plutonium-239/240	pCi/g	0.39	0.438	0.414	2
Polychlorinated biphenyl	ug/kg	8700	8700	8700	1
Potassium-40	pCi/g	3.98	3.98	3.98	1
Radium-228	pCi/g	0.3381	0.3381	0.3381	1
Strontium-90	pCi/g	6.7	6.7	6.7	1
Technetium-99	pCi/g	29.5	29.5	29.5	1
Thallium-208	pCi/g	0.1662	0.1662	0.1662	1
Thorium-228	pCi/g	0.187	0.187	0.187	1
Thorium-230	pCi/g	4.4	4.4	4.4	1
Thorium-232	pCi/g	0.179	0.179	0.179	1
Uranium	mg/kg	5724	5724	5724	1
Uranium	pCi/g	1710	1710	1710	1
Uranium-234	pCi/g	216	229	222.5	2
Uranium-235	pCi/g	30	30	30	1
Uranium-235	wt %	0.24	0.24	0.24	1
Uranium-238	pCi/g	1470	1921	1695.5	2

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Table C.101 Soil Data at Location JP-0157

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.7276	0.7276	0.7276	1
Alpha activity	pCi/g	236.66	236.66	236.66	1
Americium-241	pCi/g	1.496	1.496	1.496	1
Beryllium	mg/kg	0.79	0.79	0.79	1
Beta activity	pCi/g	340.65	340.65	340.65	1
Bismuth-212	pCi/g	0.9996	0.9996	0.9996	1
Bismuth-214	pCi/g	0.9513	0.9513	0.9513	1
Cesium-137	pCi/g	1.108	1.108	1.108	1
Chromium	mg/kg	37	37	37	1
Lead-212	pCi/g	0.7047	0.7047	0.7047	1
Lead-214	pCi/g	0.9859	0.9859	0.9859	1
Mercury	mg/kg	0.63	0.63	0.63	1
Neptunium-237	pCi/g	0.27	2.058	1.164	2
PCB-1260	ug/kg	400	400	400	1
Plutonium-239/240	pCi/g	0.1	3.77	1.935	2
Polychlorinated biphenyl	ug/kg	400	400	400	1
Potassium-40	pCi/g	8.657	8.657	8.657	1
Protactinium-233	pCi/g	0.4761	0.4761	0.4761	1
Technetium-99	pCi/g	113	113	113	1
Thorium-228	pCi/g	0.706	0.706	0.706	1
Thorium-230	pCi/g	24	24	24	1
Thorium-232	pCi/g	0.3561	0.674	0.51505	2
Uranium	mg/kg	224	224	224	1
Uranium	pCi/g	175	175	175	1
Uranium-234	pCi/g	42	63.6	52.8	2
Uranium-235	pCi/g	2.1	2.1	2.1	1
Uranium-235	wt %	0.52	0.52	0.52	1
Uranium-238	pCi/g	75	108	91.5	2

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Table C.102 Soil Data at Location JP-0160

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.3349	0.4919	0.4134	2
Bismuth-212	pCi/g	0.3348	0.3348	0.3348	1
Bismuth-214	pCi/g	0.5935	0.8248	0.70915	2
Cesium-137	pCi/g	0.696	0.889	0.7925	2
Lead-210	pCi/g	4.309	4.309	4.309	1
Lead-212	pCi/g	0.08611	0.2995	0.192805	2
Lead-214	pCi/g	0.6735	0.7655	0.7195	2
Neptunium-237	pCi/g	0.019	0.019	0.019	1
Plutonium-239/240	pCi/g	0.012	0.012	0.012	1
Potassium-40	pCi/g	5.78	5.82	5.8	2
Protactinium-231	pCi/g	0.3425	0.3425	0.3425	1
Protactinium-234m	pCi/g	1.57	2.21	1.89	2
Thallium-208	pCi/g	0.1227	0.1227	0.1227	1
Thorium-228	pCi/g	0.233	0.3435	0.2835	3
Thorium-230	pCi/g	0.607	0.629	0.618	2
Thorium-232	pCi/g	0.22	0.276	0.248	2
Uranium	mg/kg	3	3.6	3.3	2
Uranium	pCi/g	4.35	4.35	4.35	1
Uranium-234	pCi/g	0.44	1.56	0.83	3
Uranium-235	pCi/g	0.022	0.022	0.022	1
Uranium-235	wt %	0.43	0.51	0.47	2
Uranium-238	pCi/g	1	2.7	1.633	3

Table C.103 Soil Data at Location JP-0161

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	1.066	1.066	1.066	1
Bismuth-212	pCi/g	0.7818	0.7818	0.7818	1
Bismuth-214	pCi/g	0.8436	0.8436	0.8436	1
Cesium-137	pCi/g	0.415	0.415	0.415	1
Lead-210	pCi/g	2.923	2.923	2.923	1
Lead-212	pCi/g	0.9273	0.9273	0.9273	1
Lead-214	pCi/g	0.8477	0.8477	0.8477	1
Potassium-40	pCi/g	9.78	9.78	9.78	1
Protactinium-231	pCi/g	0.5734	0.5734	0.5734	1
Protactinium-234m	pCi/g	1.89	1.89	1.89	1
Thallium-208	pCi/g	0.387	0.387	0.387	1
Thorium-228	pCi/g	0.512	0.512	0.512	1
Thorium-230	pCi/g	0.369	0.369	0.369	1
Thorium-232	pCi/g	0.537	0.537	0.537	1
Thorium-234	pCi/g	2.06	2.06	2.06	1
Uranium	mg/kg	3.4	3.4	3.4	1
Uranium-234	pCi/g	0.96	0.96	0.96	1
Uranium-235	pCi/g	0.03	0.03	0.03	1
Uranium-235	wt %	0.57	0.57	0.57	1
Uranium-238	pCi/g	1.1	1.1	1.1	1

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Table C.104 Soil Data at Location JP-0162

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.9274	0.9274	0.9274	1
Bismuth-212	pCi/g	0.6626	0.6626	0.6626	1
Bismuth-214	pCi/g	0.8458	0.8458	0.8458	1
Cesium-137	pCi/g	0.206	0.206	0.206	1
Lead-212	pCi/g	0.7336	0.7336	0.7336	1
Lead-214	pCi/g	0.8528	0.8528	0.8528	1
Potassium-40	pCi/g	10.4	10.4	10.4	1
Protactinium-231	pCi/g	0.3861	0.3861	0.3861	1
Protactinium-234m	pCi/g	1.33	1.33	1.33	1
Thallium-208	pCi/g	0.2553	0.2553	0.2553	1
Thorium-228	pCi/g	0.2425	0.511	0.37675	2
Thorium-230	pCi/g	0.424	0.424	0.424	1
Thorium-232	pCi/g	0.481	0.481	0.481	1
Uranium	mg/kg	2.6	2.6	2.6	1
Uranium-234	pCi/g	0.83	0.83	0.83	1
Uranium-235	wt %	0.84	0.84	0.84	1
Uranium-238	pCi/g	0.89	0.89	0.89	1

Table C.105 Soil Data at Location JP-0163

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	1.526	1.526	1.526	1
Bismuth-212	pCi/g	1.035	1.035	1.035	1
Bismuth-214	pCi/g	1.024	1.024	1.024	1
Cesium-137	pCi/g	0.558	0.558	0.558	1
Lead-212	pCi/g	1.338	1.338	1.338	1
Lead-214	pCi/g	1.117	1.117	1.117	1
Potassium-40	pCi/g	17.2	17.2	17.2	1
Protactinium-231	pCi/g	0.9094	0.9094	0.9094	1
Thallium-208	pCi/g	0.5564	0.5564	0.5564	1
Thorium-228	pCi/g	0.626	0.626	0.626	1
Thorium-230	pCi/g	0.534	0.534	0.534	1
Thorium-232	pCi/g	0.582	0.582	0.582	1
Uranium	mg/kg	3.6	3.6	3.6	1
Uranium	pCi/g	4.97	4.97	4.97	1
Uranium-234	pCi/g	0.73	1.65	1.19	2
Uranium-235	pCi/g	0.026	0.026	0.026	1
Uranium-235	wt %	0.47	0.47	0.47	1
Uranium-238	pCi/g	1.2	3.23	2.215	2

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Table C.106 Soil Data at Location NST1S01

Analysis	Units	Minimum	Maximum	Average	Detected Count
1,2-Dimethylbenzene	ug/kg	36	36	36	1
4-Methyl-2-pentanone	ug/kg	15	15	15	1
Acetone	ug/kg	10	10	10	1
Alpha activity	pCi/g	17.19	17.19	17.19	1
Barium	mg/kg	122	122	122	1
Beta activity	pCi/g	26.96	26.96	26.96	1
Bismuth-214	pCi/g	0.481	0.481	0.481	1
Cesium-137	pCi/g	0.2593	0.2593	0.2593	1
Chromium	mg/kg	7.59	7.59	7.59	1
Ethylbenzene	ug/kg	11	11	11	1
Lead	mg/kg	29.1	29.1	29.1	1
Lead-212	pCi/g	0.226	0.226	0.226	1
Lead-214	pCi/g	0.5536	0.5536	0.5536	1
m,p-Xylene	ug/kg	22	22	22	1
PCB-1254	mg/kg	1.9	1.9	1.9	1
Polychlorinated biphenyl	mg/kg	1.9	1.9	1.9	1
Potassium-40	pCi/g	5.276	5.276	5.276	1
Protactinium-234m	pCi/g	58.58	58.58	58.58	1
Radium-228	pCi/g	0.3315	0.3315	0.3315	1
Strontium-90	pCi/g	1.4	1.4	1.4	1
Technetium-99	pCi/g	65.9	65.9	65.9	1
Thorium-228	pCi/g	0.209	0.209	0.209	1
Thorium-230	pCi/g	0.884	0.884	0.884	1
Thorium-232	pCi/g	0.175	0.1819	0.17845	2
Thorium-234	pCi/g	58.58	58.58	58.58	1
Toluene	ug/kg	12	12	12	1
Uranium	mg/kg	150	150	150	1
Uranium	pCi/g	77.1	77.1	77.1	1
Uranium-234	pCi/g	7.7	10.1	8.9	2
Uranium-235	pCi/g	0.67	0.67	0.67	1
Uranium-235	wt %	0.24	0.24	0.24	1
Uranium-238	pCi/g	50.2	65.9	58.05	2

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Table C.107 Soil Data at Location NST1S02

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.4929	0.4929	0.4929	1
Alpha activity	pCi/g	5.68	5.68	5.68	1
Barium	mg/kg	133	133	133	1
Beryllium	mg/kg	0.66	0.66	0.66	1
Beta activity	pCi/g	20.3	20.3	20.3	1
Bismuth-212	pCi/g	0.3123	0.3123	0.3123	1
Bismuth-214	pCi/g	0.517	0.517	0.517	1
Cesium-137	pCi/g	0.1664	0.1664	0.1664	1
Chromium	mg/kg	13.3	13.3	13.3	1
Lead-212	pCi/g	0.4324	0.4324	0.4324	1
Lead-214	pCi/g	0.5373	0.5373	0.5373	1
Plutonium-239/240	pCi/g	0.137	0.137	0.137	1
Potassium-40	pCi/g	6.296	6.296	6.296	1
Protactinium-231	pCi/g	0.6072	0.6072	0.6072	1
Protactinium-234m	pCi/g	26.66	26.66	26.66	1
Technetium-99	pCi/g	82	82	82	1
Thallium-208	pCi/g	0.1949	0.1949	0.1949	1
Thorium-228	pCi/g	0.238	0.238	0.238	1
Thorium-230	pCi/g	1.19	1.19	1.19	1
Thorium-232	pCi/g	0.221	0.221	0.221	1
Thorium-234	pCi/g	26.66	26.66	26.66	1
Toluene	ug/kg	15	15	15	1
Uranium	mg/kg	41.4	41.4	41.4	1
Uranium	pCi/g	33.7	33.7	33.7	1
Uranium-234	pCi/g	3	6.45	4.725	2
Uranium-235	pCi/g	0.25	0.25	0.25	1
Uranium-235	wt %	0.28	0.28	0.28	1
Uranium-238	pCi/g	13.9	29.7	21.8	2

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Table C.108 Soil Data at Location NST1S03

Analysis	Units	Minimum	Maximum	Average	Detected Count
Acetone	ug/kg	35	35	35	1
Actinium-228	pCi/g	0.9062	0.9062	0.9062	1
Alpha activity	pCi/g	4.17	4.17	4.17	1
Arsenic	mg/kg	5.76	5.76	5.76	1
Barium	mg/kg	83.1	83.1	83.1	1
Beryllium	mg/kg	0.68	0.68	0.68	1
Beta activity	pCi/g	12.65	12.65	12.65	1
Bismuth-212	pCi/g	0.5111	0.5111	0.5111	1
Bismuth-214	pCi/g	0.7815	0.7815	0.7815	1
Chromium	mg/kg	12.3	12.3	12.3	1
Lead-212	pCi/g	0.5819	0.5819	0.5819	1
Lead-214	pCi/g	0.7868	0.7868	0.7868	1
Potassium-40	pCi/g	8.516	8.516	8.516	1
Protactinium-231	pCi/g	0.2158	0.2158	0.2158	1
Protactinium-233	pCi/g	0.1369	0.1369	0.1369	1
Protactinium-234m	pCi/g	0.6507	0.6507	0.6507	1
Strontium-90	pCi/g	2.5	2.5	2.5	1
Technetium-99	pCi/g	12.9	12.9	12.9	1
Thallium-208	pCi/g	0.2177	0.2177	0.2177	1
Thorium-228	pCi/g	0.2365	0.321	0.27875	2
Thorium-230	pCi/g	0.339	0.339	0.339	1
Thorium-232	pCi/g	0.361	0.361	0.361	1
Thorium-234	pCi/g	0.6507	0.6507	0.6507	1
Uranium	mg/kg	2	2	2	1
Uranium-234	pCi/g	0.55	0.55	0.55	1
Uranium-235	pCi/g	0.025	0.025	0.025	1
Uranium-238	pCi/g	0.66	0.66	0.66	1

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Table C.109 Soil Data at Location NST2S01

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.4131	0.4131	0.4131	1
Alpha activity	pCi/g	10.91	10.91	10.91	1
Arsenic	mg/kg	7.48	7.48	7.48	1
Barium	mg/kg	81.1	81.1	81.1	1
Beryllium	mg/kg	0.75	0.75	0.75	1
Beta activity	pCi/g	53.11	53.11	53.11	1
Bismuth-212	pCi/g	0.3944	0.3944	0.3944	1
Bismuth-214	pCi/g	0.6182	0.6182	0.6182	1
Cesium-137	pCi/g	0.1243	0.1243	0.1243	1
Chromium	mg/kg	26.3	26.3	26.3	1
Lead	mg/kg	28.9	28.9	28.9	1
Lead-212	pCi/g	0.3977	0.3977	0.3977	1
Lead-214	pCi/g	0.5857	0.5857	0.5857	1
Potassium-40	pCi/g	7.77	7.77	7.77	1
Protactinium-231	pCi/g	0.4374	0.4374	0.4374	1
Protactinium-234m	pCi/g	7.383	7.383	7.383	1
Technetium-99	pCi/g	67.6	67.6	67.6	1
Thorium-228	pCi/g	0.314	0.314	0.314	1
Thorium-230	pCi/g	0.749	0.749	0.749	1
Thorium-232	pCi/g	0.2456	0.277	0.2613	2
Thorium-234	pCi/g	7.383	7.383	7.383	1
Toluene	ug/kg	25	25	25	1
Uranium	mg/kg	23.1	23.1	23.1	1
Uranium	pCi/g	12	12	12	1
Uranium-234	pCi/g	2.2	3.64	2.92	2
Uranium-235	pCi/g	0.18	0.18	0.18	1
Uranium-235	wt %	0.43	0.43	0.43	1
Uranium-238	pCi/g	7.8	8.11	7.955	2

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Table C.110 Soil Data at Location NST2S02

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	0.6114	0.6114	0.6114	1
Alpha activity	pCi/g	62.23	62.23	62.23	1
Arsenic	mg/kg	5.25	5.25	5.25	1
Barium	mg/kg	107	107	107	1
Beryllium	mg/kg	0.62	0.62	0.62	1
Beta activity	pCi/g	122.73	122.73	122.73	1
Bismuth-212	pCi/g	0.333	0.333	0.333	1
Bismuth-214	pCi/g	0.6197	0.6197	0.6197	1
Cesium-137	pCi/g	0.5336	0.5336	0.5336	1
Chromium	mg/kg	9.86	9.86	9.86	1
Ethylbenzene	ug/kg	11	11	11	1
Lead	mg/kg	30.2	30.2	30.2	1
Lead-212	pCi/g	0.246	0.246	0.246	1
Lead-214	pCi/g	0.5637	0.5637	0.5637	1
Polychlorinated biphenyl	mg/kg	1.1	1.1	1.1	1
Potassium-40	pCi/g	5.555	5.555	5.555	1
Protactinium-231	pCi/g	0.7593	0.7593	0.7593	1
Protactinium-234m	pCi/g	43.04	43.04	43.04	1
Strontium-90	pCi/g	4	4	4	1
Technetium-99	pCi/g	23.6	23.6	23.6	1
Thallium-208	pCi/g	0.08389	0.08389	0.08389	1
Thorium-228	pCi/g	0.2278	0.27	0.2489	2
Thorium-230	pCi/g	0.733	0.733	0.733	1
Thorium-232	pCi/g	0.256	0.256	0.256	1
Thorium-234	pCi/g	43.04	43.04	43.04	1
Toluene	ug/kg	18	18	18	1
Uranium	mg/kg	311	311	311	1
Uranium	pCi/g	81.2	81.2	81.2	1
Uranium-234	pCi/g	32.7	33	32.85	2
Uranium-235	pCi/g	2.2	2.2	2.2	1
Uranium-235	wt %	0.58	0.58	0.58	1
Uranium-238	pCi/g	46.7	104	75.35	2

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Table C.111 Soil Data at Location NST2S03

Analysis	Units	Minimum	Maximum	Average	Detected Count
Acetone	ug/kg	38	38	38	1
Actinium-228	pCi/g	0.9286	0.9286	0.9286	1
Alpha activity	pCi/g	152.3	152.3	152.3	1
Americium-241	pCi/g	1.956	1.956	1.956	1
Arsenic	mg/kg	13.7	13.7	13.7	1
Barium	mg/kg	85.9	85.9	85.9	1
Beryllium	mg/kg	0.68	0.68	0.68	1
Beta activity	pCi/g	301.01	301.01	301.01	1
Bismuth-212	pCi/g	0.7006	0.7006	0.7006	1
Bismuth-214	pCi/g	1.121	1.121	1.121	1
Cesium-137	pCi/g	1.057	1.057	1.057	1
Chromium	mg/kg	81	81	81	1
Lead-212	pCi/g	0.8039	0.8039	0.8039	1
Lead-214	pCi/g	1.052	1.052	1.052	1
Neptunium-237	pCi/g	0.55	1.169	0.8595	2
Plutonium-239/240	pCi/g	1.1	1.1	1.1	1
Potassium-40	pCi/g	7.602	7.602	7.602	1
Protactinium-233	pCi/g	0.372	0.372	0.372	1
Protactinium-234m	pCi/g	16.71	16.71	16.71	1
Radium-223	pCi/g	0.5283	0.5283	0.5283	1
Strontium-90	pCi/g	5	5	5	1
Technetium-99	pCi/g	281	281	281	1
Thallium-208	pCi/g	0.3394	0.3394	0.3394	1
Thorium-228	pCi/g	0.79	0.79	0.79	1
Thorium-230	pCi/g	55.9	55.9	55.9	1
Thorium-232	pCi/g	0.77	0.77	0.77	1
Thorium-234	pCi/g	16.71	16.71	16.71	1
Uranium	mg/kg	59.3	59.3	59.3	1
Uranium	pCi/g	33.9	33.9	33.9	1
Uranium-234	pCi/g	12.4	14.2	13.3	2
Uranium-235	pCi/g	0.69	0.69	0.69	1
Uranium-235	wt %	0.61	0.61	0.61	1
Uranium-238	pCi/g	18.9	19.8	19.35	2

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Table C.112 Soil Data at Location NST2S04

Analysis	Units	Minimum	Maximum	Average	Detected Count
Actinium-228	pCi/g	1.934	1.934	1.934	1
Alpha activity	pCi/g	2.3	2.3	2.3	1
Arsenic	mg/kg	11.5	11.5	11.5	1
Barium	mg/kg	300	300	300	1
Beryllium	mg/kg	1.86	1.86	1.86	1
Beta activity	pCi/g	21.16	21.16	21.16	1
Bismuth-212	pCi/g	1.655	1.655	1.655	1
Bismuth-214	pCi/g	2.712	2.712	2.712	1
Chromium	mg/kg	14.2	14.2	14.2	1
Lead-210	pCi/g	2.646	2.646	2.646	1
Lead-212	pCi/g	1.753	1.753	1.753	1
Lead-214	pCi/g	2.664	2.664	2.664	1
Potassium-40	pCi/g	12.17	12.17	12.17	1
Protactinium-231	pCi/g	0.9513	0.9513	0.9513	1
Protactinium-234m	pCi/g	2.386	2.386	2.386	1
Thallium-208	pCi/g	0.346	0.346	0.346	1
Thorium-228	pCi/g	0.269	0.269	0.269	1
Thorium-230	pCi/g	0.313	0.313	0.313	1
Thorium-232	pCi/g	0.265	0.5376	0.4013	2
Thorium-234	pCi/g	2.386	2.386	2.386	1
Uranium	mg/kg	1.9	1.9	1.9	1
Uranium	pCi/g	5.4	5.4	5.4	1
Uranium-234	pCi/g	0.56	1.21	0.885	2
Uranium-235	pCi/g	0.045	0.045	0.045	1
Uranium-235	wt %	0.33	0.33	0.33	1
Uranium-238	pCi/g	0.65	4.11	2.38	2

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Table C.113 Soil Data at Location NST 2S05

Analysis	Units	Minimum	Maximum	Average	Detected Count
Acetone	ug/kg	51	55	53	2
Actinium-228	pCi/g	0.7773	5.05	2.91365	2
Alpha activity	pCi/g	3.07	5.02	4.045	2
Barium	mg/kg	49.1	50.8	49.95	2
Beryllium	mg/kg	0.51	0.59	0.55	2
Beta activity	pCi/g	7.78	8.61	8.195	2
Bismuth-212	pCi/g	0.6299	4.705	2.66745	2
Bismuth-214	pCi/g	0.4899	5.561	3.02545	2
Chromium	mg/kg	8.37	10.4	9.385	2
Lead-212	pCi/g	0.4824	4.629	2.5557	2
Lead-214	pCi/g	0.5656	5.456	3.0108	2
Potassium-40	pCi/g	5.159	52.21	28.6845	2
Protactinium-231	pCi/g	0.2219	2.645	1.43345	2
Strontium-90	pCi/g	1.3	2.7	2	2
Technetium-99	pCi/g	15.6	15.6	15.6	1
Thallium-208	pCi/g	0.1716	0.1716	0.1716	1
Thorium-228	pCi/g	0.2206	0.364	0.29887	3
Thorium-230	pCi/g	0.394	1.4	0.897	2
Thorium-232	pCi/g	0.288	2.282	0.95733	3
Uranium	mg/kg	1.4	1.65	1.525	2
Uranium	pCi/g	17.9	17.9	17.9	1
Uranium-234	pCi/g	0.41	6.48	2.45	3
Uranium-235	pCi/g	0.052	0.052	0.052	1
Uranium-235	wt %	0.51	0.56	0.535	2
Uranium-238	pCi/g	0.47	11.1	4.04	3

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Groundwater

Table C.114 Groundwater Data at Various Locations

Location	Analysis	Units	Minimum	Maximum	Average	Detected Count
MW 100	Acetone	ug/L	11	12	11.5	2
	Alpha activity	pCi/L	4.39	4.39	4.39	1
	Beta activity	pCi/L	14.61	18.27	16.44	2
MW 121	Acetone	ug/L	13	13	13	1
	Beta activity	pCi/L	123.92	123.92	123.92	1
MW 122	Acetone	ug/L	14	14	14	1
	Beta activity	pCi/L	63.53	63.53	63.53	1
MW 133	Acetone	ug/L	17	17	17	1
	Beta activity	pCi/L	21.85	21.85	21.85	1
	Plutonium-239/240	pCi/L	0.305	0.305	0.305	1
	Technetium-99	pCi/L	22.5	22.5	22.5	1
MW135	Acetone	ug/L	16	16	16	1
	Beta activity	pCi/L	97.59	97.59	97.59	1
	Technetium-99	pCi/L	86.9	86.9	86.9	1
	Trichloroethene	ug/L	4	4	4	1
MW137	Acetone	ug/L	14	14	14	1
	Beta activity	pCi/L	106.89	106.89	106.89	1
	Technetium-99	pCi/L	124	124	124	1
	Trichloroethene	ug/L	3	3	3	1
MW138	Acetone	ug/L	15	15	15	1
	Beta activity	pCi/L	44.7	44.7	44.7	1
	Technetium-99	pCi/L	32.5	32.5	32.5	1
MW 146	Acetone	ug/L	15	15	15	1
	Plutonium-239/240	pCi/L	0.531	0.531	0.531	1
MW 152	Acetone	ug/L	14	14	14	1
	Beta activity	pCi/L	122.07	122.07	122.07	1
	Technetium-99	pCi/L	148	148	148	1
	Trichloroethene	ug/L	1	1	1	1
MW 194	Acetone	ug/L	16	16	16	1
	Beta activity	pCi/L	6.88	6.88	6.88	1
MW 199	Acetone	ug/L	26	26	26	1
	Beta activity	pCi/L	12.72	12.72	12.72	1
TVA W-1	Alpha activity	pCi/L	18.51	18.51	18.51	1
	Beta activity	pCi/L	24.45	24.45	24.45	1

DOJ Special Investigations Data

Surface Water

Table C.115 Surface Water Data at Various Locations

Location	Analysis	Units	Minimum	Maximum	Average	Detected Count
DOESW-3	Acetone	ug/L	11	11	11	1
	Alpha activity	pCi/L	20.42	20.42	20.42	1
	Beta activity	pCi/L	48.77	48.77	48.77	1
	PCB-1248	ug/L	0.2	0.2	0.2	1
	Polychlorinated biphenyl	ug/L	0.2	0.2	0.2	1
	Technetium-99	pCi/L	31.9	31.9	31.9	1
	Thorium-230	pCi/L	3.96	3.96	3.96	1
DOESW-9	Beta activity	pCi/L	6.52	6.52	6.52	1
K001	Acetone	ug/L	12	12	12	1
	Beta activity	pCi/L	46.63	46.63	46.63	1
K010	Acetone	ug/L	10	10	10	2
	Beta activity	pCi/L	8.42	15.71	12.065	2
L10	Acetone	ug/L	10	10	10	1
	Alpha activity	pCi/L	4.51	4.51	4.51	1
L223	Acetone	ug/L	11	11	11	1
	Beta activity	pCi/L	10.73	10.73	10.73	1
L5	Acetone	ug/L	13	13	13	1
	Beta activity	pCi/L	19.27	19.27	19.27	1
L8	Acetone	ug/L	15	15	15	1
	Beta activity	pCi/L	22.83	22.83	22.83	1

Appendix D: Groundwater Contamination

This appendix contains excerpts from the report, *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 1999 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2000b) issued in May 2000. The complete document is available through the DOE Environmental Information Center in Kevil, Kentucky. Most of the information presented in the report is provided here; however, figures and maps are not reproduced in this publication. Where omissions from the original report occur, the text is bolded with an explanation of how to find the omitted information. Where Appendix A and Appendix B are referenced, these are appendices to the original report and are not included in this ASER.

1. INTRODUCTION

The U.S. Department of Energy's (DOE's) Paducah Gaseous Diffusion Plant (PGDP) has been the subject of intense environmental monitoring over the last decade. Annual DOE reports present a summary of yearly monitoring results. These yearly monitoring results have been incorporated within the database of site-wide investigations, as they occurred. The previous site-wide investigations have included the following:

- *Results of the Site Investigation, Phase I, Paducah Gaseous Diffusion Plant, Kentucky* (CH2M HILL 1991);
- *Results of the Site Investigation, Phase II, Paducah Gaseous Diffusion Plant, Kentucky* (CH2M HILL 1992);
- *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III* (MMES 1992); and
- *Northeast Plume Preliminary Characterization Summary Report* (DOE 1995).

More recently, the DOE has completed several remedial investigations of known or suspected sources to the main off-site groundwater plumes migrating from the PGDP. The investigation reports include:

- *Remedial Investigation Report for the Waste Area Grouping 6 at the Paducah Gaseous Diffusion Plant, Paducah Kentucky* (DOE 1999a);
- *Remedial Investigation Report for the Waste Area Grouping 27 at the Paducah Gaseous Diffusion Plant, Paducah Kentucky* (DOE 1999b);
- *Remedial Investigation Report for the Waste Area Grouping 28 at the*

Paducah Gaseous Diffusion Plant, Paducah Kentucky (DOE 2000a);

- *Data Report for the Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2000b); and

- *Site Evaluation Report for Waste Area Grouping 8 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2000c).

This report is the first of a series of annual interpretations of groundwater data for the PGDP, including revision of the site groundwater plume maps, to assess the extent of trichloroethene (TCE) and technetium-99 (^{99}Tc) in the shallow aquifer for the preceding year. The plume maps include data from the above referenced documents in addition to routine groundwater monitoring data collected through the end of calendar year 1999. Significant revisions to the 1998 edition of the plume maps are discussed in Section 4. These reports provide a basis for timely incorporation of routine groundwater monitoring and characterization data for planned remedial actions.

2. SETTING

The PGDP is located in the Jackson Purchase region of western Kentucky, approximately 16.1 km (10 miles) west of Paducah, Kentucky and 5.6 km (3.5 miles) south of the Ohio River. Cretaceous marine sediments of the Mississippi Embayment, resting upon a Mississippian-age carbonate bedrock, underlie the PGDP at depth. Buried river deposits of the ancestral Tennessee River unconformably overlie the Cretaceous sediments directly beneath the PGDP. A thick gravel deposit at a general depth of 18.3 m (60 ft) below most of the PGDP forms the shallow aquifer, the Regional Gravel Aquifer (RGA). The RGA is the main conduit for groundwater flow to the north, where groundwater discharges into the Ohio River, and the main pathway for off-site contaminant plume migration. **Figure 1** presents a general cross-section of the site geology, while **Figure 2** illustrates the main features of the groundwater flow systems. **[These figures are not provided in this ASER; however, they are available in the report *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 1999 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (BJC/PAD-169), in the DOE Environmental Information Center in Kevil, Kentucky.]**

The common solvent TCE and the man-made radioisotope, ^{99}Tc, are the most widespread groundwater contaminants associated with the PGDP. TCE occurs as pure phase (free-product) dense non-aqueous phase liquid (DNAPL) at multiple locations in the silts and clays overlying the RGA and, most probably, in the RGA itself at some locations. Technetium-99 is retained within shallow silt and clay units. Both contaminants have resulted in large-scale dissolved-phase plumes that are migrating from the PGDP toward the Ohio River. Table 1 presents a summary of the PGDP groundwater plumes. **Figure 3 [not provided]** shows the location of each groundwater plume as well as some of the facilities, monitoring wells, and soil borings of the PGDP.

DOE has taken three discrete actions to contain the groundwater contamination and mitigate the risk to the public associated with groundwater. Two separate interim remedial actions installed pump-and-treat systems in the Northwest and Northeast Plumes. Both pump-and-treat systems consist of well fields at the leading edge of the high concentrations core of the plumes. The Northwest Plume treatment system also includes a well field near the PGDP security fence. To minimize risks to residents and businesses north of the PGDP, DOE maintains a Water Policy, whereby DOE provides municipal water to area residents and businesses.

Table 1. PGDP groundwater plumes

Plume	Primary off-site contaminants	Approximate maximum off-site contaminant levels	Off-site plume length
Northeast	TCE	TCE = 1500 µg/L	3.5 km (2.2 miles)
Northwest	TCE and ^{99}Tc	TCE = 10,000 µg/L ^{99}Tc = 3000 pCi/L	4.1 km (2.5 miles)
Southwest	TCE and ^{99}Tc	TCE = 480 µg/L ^{99}Tc = 2470 pCi/L	0.5 km (0.3 miles)
Technetium-99	^{99}Tc	^{99}Tc = 400 pCi/L	5.3 km (3.3 miles)

3. REVISED PLUME MAPS

A primary component of the annual groundwater report is a revision of the site maps of TCE and ^{99}Tc levels in the RGA. These maps (presented in Appendix A) represent the contaminant extent during the preceding year based upon 1) analysis of groundwater samples collected during the previous year, 2) temporal trends in groundwater samples collected from monitoring wells, and 3) projected contaminant levels based on previous analyses and a conceptual model of contaminant trends. Appendix B includes plots of contaminant levels over time for trends cited in this report. The attached maps are based on the available TCE and ^{99}Tc analyses of groundwater found in DOE's Oak Ridge Environmental Information System (OREIS) database at the end of calendar year (CY) 1999. These data include records for 162 RGA wells and piezometers and 976 depth-discrete samples collected from the RGA. The data set (Appendix B) incorporates analyses of the Remedial Investigations (RIs) of Waste Area Groupings (WAGs) 6 (DOE 1999a), 27 (DOE 1999b), and 28 (DOE 2000a), as well as the Sitewide Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination (DOE 2000b) and the Site Evaluation Report for WAG 8 (DOE 2000c). Data from the PGDP's most recent RI, WAG 3, had not been appended to the OREIS database at the end of CY 1999. Therefore, the WAG 3 data are not included. However, WAG 3 data will be included in the evaluation of contaminant extent beginning with the CY 2000 annual interpretation of groundwater data for the PGDP.

Maps of TCE and ^{99}Tc are presented at two scales to best present the greater available detail for the PGDP plant, but are shown with less available detail for the larger off-site area impacted by the PGDP. The plant map (1:4800 scale) covers the 303 ha (748 acres) contained within the PGDP security fence. Metropolis Lake Road and Bethel Church Road conveniently define the east and west boundaries, respectively, of the potential area impacted by the PGDP groundwater contamination. This larger area map (1:12,000 scale) addresses approximately 5950 ha (14,700 acres) of the DOE reservation and other lands between the plant and the Ohio River. Each map represents contaminant levels observed or projected in RGA monitoring wells during 1999, plus data from temporary characterization borings. These maps are composites of three sets of working maps of the lower, middle, and upper RGA [elevations 76.2 to 89.9 m (250 to 295 ft), 89.9 to 93.0 m (295 to 305 ft), and 93.0 to 97.5 m (305 to 320 ft) above mean sea level]. Letter-size versions of the working and composite maps are included in Appendix A. Additional discussion of how the maps were developed is presented in Appendix B. The data set and trend plots for key wells used in the interpretation are also included in Appendix B.

4. SIGNIFICANT REVISIONS TO PREVIOUS PLUME MAPS

The site-wide PGDP plume maps were last revised in 1998. More recent investigations provide information in the area of the known and suspected sources of groundwater contamination and along the PGDP security fence line. Data sets added to the OREIS database since the last revision include the WAG 27 RI (DOE 1999b), the WAG 28 RI (DOE 2000a), the Sitewide Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination (DOE 2000b), and the WAG 8 Site Evaluation (DOE 2000c). These additional data have permitted confirmation and enhanced definition of the Southwest Plume as well as refinements to the distribution of contaminants on-site and identification of five new potential source areas. The soil borings of the Sitewide Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination (DOE 2000b), in particular, provided contaminant profiles with depth in the area of a main effluent ditch in the north–central area of the PGDP, the North/South Diversion Ditch, and filled gaps in a transect around the east, north, and west sides of the plant. These analyses appear to define a distinct plume of both TCE and ^{99}Tc that is sourced in the north–central area of the plant, near the C-616 effluent clarifier, and migrates to the northeast. The following list highlights the significant revisions to the previous plume maps:

- Confirmation and definition of Southwest Plume (WAG 27 RI / Sitewide Evaluation)
  - confirmed suspected existence of separate Southwest Plume,
  - defined extent of plume,
  - maximum concentrations measured – 10,000 µg/L TCE and 3710 pCi/L ^{99}Tc;
- New potential source area – northeast of Oil Landfarm [Solid Waste Management Unit (SWMU) 1] (Sitewide Evaluation)
  - primary source for Southwest Plume,
  - source of both TCE and ^{99}Tc;
- New potential source area – C-746-C area (Sitewide Evaluation)
  - interpreted to contribute to Northeast Plume,
  - maximum concentrations measured – 2200 µg/L TCE and 1500 pCi/L ^{99}Tc;
- New potential source area – C-310 Building area (WAG 28)
  - interpreted to contribute to Southwest Plume,
  - maximum concentrations measured – 330 µg/L TCE and 1390 pCi/L ^{99}Tc;
- New potential source area – C-410 Building area (Data reinterpretation)
  - interpreted to contribute to Northeast Plume;
- New potential source area – Kellogg Building Pad (SWMU 99) (WAG 28)
  - MW256 adjacent to pad indicates increase in ^{99}Tc levels in RGA;
  - soils data from WAG 28 suggest that equipment stored on pad may be source;
- "Depleting source" for Northeast Plume – northwest corner of C-333 (WAG 28)
  - TCE concentrations in PZ118 declined from 6700 to 1000 µg/L since Phase IV investigation;
  - TCE concentrations in MW255 and MW258 dropped by approximately 50% over same period.

The following subsections describe the main revisions to the groundwater plume maps and contaminant trends.

4.1 Northeast Plume

4.1.1 Trichloroethene

Within the Northeast Plume, contaminant levels above 5 µg/L cover a large area as a result of several potential source areas. The highest concentrations (as high as 1500 µg/L in MW294) are found in a narrow core along the eastern edge of the plume. The most upgradient source area for this high concentration area appears to be near the northwest corner of the C-333 Process Building. An additional source area contributing to the high concentration area appears to be in the vicinity of the C-340 Metals Reduction Facility (1400 µg/L detected). Nevertheless, the source to the main plume centroid of the Northeast Plume remains undefined. Other areas that appear to be contributing to the Northeast Plume include the northeast corner of the C-400 Building and the C-410 Building. TCE concentrations of 1700 µg/L were measured immediately northeast of the C-400 Building during the WAG 6 investigation (DOE 1999a). Further east, samples collected from MW260 have indicated TCE concentrations above 900 µg/L, interpreted to be sourced from the northeast corner of the C-400 Building.

Of particular note, TCE concentrations in some of the monitoring wells associated with the main high concentration area near and within the plant boundaries have shown a significant decline in TCE concentrations. In 1995, samples from MW258, immediately east of the C-755 Subcontractor Staging Area, had initial TCE concentrations above 2300 µg/L. The most recent samples (11/99) collected from this well contained only 1100 µg/L. This trend of declining TCE levels suggests the DNAPL source zone may be rapidly depleting.

4.1.2 Technetium-99

Contaminant levels are generally less than 25 pCi/L off-site and are only greater than 100 pCi/L at a few discrete sources. The most upgradient source area appears to be the northwest corner of the C-333 Process Building. Lesser source areas downgradient of C-333 are the C-340 Building (27 to 382 pCi/L detected) and a classified materials storage area located on the foundation of the former Kellogg Building/ SWMU 99 (137 pCi/L detected). Increasing ^{99}Tc activity in monitoring well MW256 is indicative of the Kellogg Building area source and portends an off-site level greater than 25 pCi/L in a discrete area of the Northeast Plume if remedial actions are not initiated.

Both the northeast corner of the C-400 Building and the C-410 Building appear to be source areas of discrete centroids of contamination moving to the east within the broad boundaries of the Northeast Plume. Technetium-99 activity is greater than 900 pCi/ L in the upper RGA beneath the northeast corner of the C-400 Building and interpreted to be greater than 100 pCi/L beneath the C-410 Building.

4.2 Northwest Plume

4.2.1 Trichloroethene

Compared to the Northeast Plume, TCE contamination in the Northwest Plume covers a smaller geographic area. However, the TCE concentrations in the core of the Northwest Plume are higher than the TCE concentrations in the Northeast Plume. Outside the security fence, TCE concentrations measured in the core of the Northwest Plume during 1999 were as high as 9100 µg/L (MW248), as compared to the maximum concentration seen in the Northeast Plume, 1500 µg/L. Immediately downgradient of the north extraction well field, measured TCE concentrations during 1999 were as high as 1500 µg/L (MW236).

A possible TCE source area upgradient of the C-400 Building was identified in the vicinity of the C310 Product Building during the WAG 28 RI (DOE 2000a). Alternate interpretations of this area are possible which may include the TCE being associated with either the Northeast Plume or Southwest Plume

contamination areas. Regardless of the direction the TCE from the C-310 area may be migrating, the TCE sources at the southeast corner of the C-400 Building remain the primary probable sources for the Northwest Plume.

4.2.2 Technetium-99

The Northwest Plume includes a ^{99}Tc activity near 900 pCi/L at the north well field and near 3970 pCi/L at the south well field. A centroid of greater than 100 pCi/L extends to Little Bayou Creek, where the groundwater discharges to the creek.

Groundwater data of the WAG 6 RI indicate an upgradient source of ^{99}Tc near the southeast corner of the C-400 Cleaning Building. However, the primary source of ^{99}Tc remains the northwest corner of the C-400 Building and the adjacent reach of the North/South Diversion Ditch (10,000 to 40,000 pCi/L in the basal RGA).

4.3 Southwest Plume

4.3.1 Trichloroethene

Groundwater sampling conducted as part of the WAG 27 RI (DOE 1999b) confirmed the existence of the Southwest Plume. Additional sampling during the Sitewide Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination (DOE 2000b) provided additional detail of the plume's structure and identified a previously unknown potential source at SWMU 4. The maximum measured TCE concentration on-site was 10,000 µg/L in boring DG-030, located immediately west of SWMU 4. Outside the plant fence, the maximum measured TCE concentration was 480 µg/L in DG-016.

Like the Northeast Plume, the Southwest Plume appears to collect TCE from multiple sources including the C-720 area, the Oil Landfarm (SWMU 1), and the Cylinder Drop Test Site (SWMU 91), with the major source being SWMU 4. Other potential source areas, depending on interpretation, include the C-310 Building and the southwest corner of C-400.

4.3.2 Technetium-99

The WAG 27 RI (DOE 1999b) and the Sitewide Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination (DOE 2000b) provide the primary data used to define the extent of contamination in the Southwest Plume. Highest levels (3710 pCi/L, taken from soil boring 001-182 in the lower RGA) are derived from the burial ground area of SWMU 4. Lesser discrete upgradient sources are found to the east at the C-310 Building, the northeast corner of the C-720 Building and the north side of the C-409 Building. The off-site plume of $\geq$ 900 pCi/L is restricted to within approximately 183 m (600 ft) of the PGDP security fence line. Technetium-99 activity of $\geq$ 25 pCi/L extends to New Water Line Road on the west side of the plant.

4.4 Technetium-99 Plume

4.4.1 Technetium-99

Only limited data are available to define the source and extent of the Technetium-99 Plume. The plume source, which is generating at least several hundred pCi/L of ^{99}Tc in the nearby RGA, appears to be located in the area of the northwest end of the C-616-E lagoon. Groundwater analyses of monitoring well MW152 document up to 195 pCi/L in the RGA near the Shawnee Steam Plant. The plume is projected to extend to the Shawnee Steam Plant water intake canal, off the Ohio River, where both the PGDP and Shawnee Steam Plant derive their plant process water (a collective withdrawal of 10 to 20 million gallons of water per day). During the revision of the off-site Technetium-99 Plume map, the trend of the plume was moved east to project under the northwest corner of the C-746-U landfill where monitoring well MW275 intercepts water with a ^{99}Tc activity of 246 pCi/L. The PGDP's North/South Diversion Ditch is a

potential alternative source of the ^{99}Tc activity observed in MW275 area.

4.5 Other Areas of Contamination

Groundwater analyses of the Sitewide Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination (DOE 2000b) are key to the definition of a previously unsuspected source of dissolved TCE and ^{99}Tc in the vicinity of the C746-C scrapyard. The plume is projected to extend east–northeast and makes up the leading edge of the Northeast Plume.

The maximum TCE concentration measured in the core of the off-site plume was 2200 µg/L (soil boring DG-007) in the middle of the RGA. Concentrations in excess of 100 µg/L are interpreted to extend to the east–northeast as part of an area previously identified during the Phase IV investigation and merges with the main body of the Northeast Plume.

Technetium-99 activity exceeds 900 pCi/L in the core of the off-site plume. The extent of the off-site ^{99}Tc plume, as defined by an activity of 25 pCi/L, is primarily limited to the area north of the plant and east of the C-616 clarifier and within 450 m (1500 ft) of the security fence.

Another area of persistent TCE contamination appears to originate near the northwest corner of the C-746-S and -T landfills. TCE concentrations are low (≥ 25 µg/L). Since no data are available between the Northwest Plume and the landfill area, the source of the TCE cannot be confirmed at this time.

5. TRENDS AT THE PGDP PUMP-AND-TREAT FACILITIES

Monitoring well systems located at the Northeast Plume Containment System and at both well fields of the Northwest Plume Groundwater System provide a means to assess the effectiveness of the interim remedial actions. The following sections summarize the interpretation of trends of groundwater contamination within the well fields over the life of the operations. Pumping has been ongoing in the Northwest Plume well fields since 1995. Operation of the Northeast Plume well field began in 1996.

5.1.1 Northeast Plume Containment System

5.1.1 Trichloroethene

Contaminant trends for the monitoring wells associated with the extraction well field show that TCE levels have decreased significantly since installation of the extraction wells. It does appear, however, that the easternmost extraction well is not totally effective in containing the high concentration core. Samples from the two downgradient wells, MW293 and MW294, are still above 1000 g/L; however, the TCE levels have dropped by almost half from the concentrations measured when pumping began in 1996.

5.1.2. Technetium-99

All analyses of groundwater from the Northeast Plume facility are less than the 25 pCi/L action limit for ^{99}Tc.

5.2.2 Northwest Plume Containment System

5.2.1 Trichloroethene

South Well Field

TCE concentrations in the downgradient monitoring wells of the South Well Field clearly show that the high concentration core (≥ 1000 µg/L) is being captured by the two extraction wells. It does appear that the extraction field is more effective capturing the west side of the plume since TCE contaminant levels in the

downgradient well on the east side of the plume (MW242) remain above 100 µg/L.

North Well Field

The monitoring well data for the north well field suggest that, like the South Well Field, the North Well Field is more effective in capturing the west side of the plume than the east side. The two downgradient wells on the east side of the plume have shown steady increases in TCE concentrations to over 1000 µg/L over the past year and a half. For the last half of 1999, most of the wells in the North Well Field have shown an increase in TCE concentrations, suggesting the possibility that a volume of groundwater containing a higher concentration of TCE is beginning to migrate through the area.

5.2.2 Technetium-99

South Well Field

Groundwater analyses for monitoring wells of the South Well Field convincingly demonstrate capture of the ≥ 900 pCi/L plume centroid. In general, the extraction well field is apparently capturing the west side of the plume (≥ 25 pCi/L) although groundwater containing several hundred pCi/L ^{99}Tc is migrating past the east side of the well field.

During December 1999, monitoring wells MW-245 (on the west side of the well field) and MW-248 (located between the two extraction wells) experienced a sharp increase in ^{99}Tc levels. Contaminant trends suggest these detections are an aberration that will not be repeated. However, it remains possible that CY 2000 analyses may suggest a significant shift of the plume centroid to the west. Groundwater monitoring results will continue to be assessed to evaluate shifts in the plume location.

North Well Field

Although less definitive, ^{99}Tc analyses for the North Well Field suggest that the extraction wells (particularly EW 229) are capturing the > 900 pCi/L centroid. It appears that both extraction wells, together, probably capture the west side of the plume. Technetium-99 activities of > 500 pCi/L continue to migrate past the east side of the well field.

The analyses of 1999 reveal a slight increase in ^{99}Tc activity on the west side of the plume during the fourth quarter. Technetium-99 levels in monitoring wells on the east side of the well field continue a trend begun in 1998 of sharply increased activity.

6. USES OF THIS REPORT

This evaluation of groundwater contaminant trends for CY 1999 supports several goals of the PGDP environmental program. Foremost, the updated plume maps and definition of trends will be used in the preparation of the Groundwater Operable Unit Feasibility Study to provide the following information:

- define additional areas contributing significant contamination to the RGA,
- scope the dimensions of potential remedial actions, and
- refine the extent of off-site areas that will be addressed by temporary or permanent institutional controls.

This same assessment will support the ongoing evaluation of the adequacy of DOE's Water Policy and effectiveness of the PGDP groundwater monitoring program. To this end, this report will be included as an appendix to the 1999 Annual Site Environmental Report. In addition, the trends and extent of contamination defined by this report will help identify areas of groundwater/surface water interaction to be considered in the upcoming RI of the Surface Water Operable Unit.

7. REFERENCES

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DOE 2000b. *Data Report for the Sitewide Remedial Evaluation for Source Areas Contributing to Off-Site Groundwater Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-1845/D1, January.

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MMES (Martin Marietta Energy Systems, Inc.) 1992. *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III*, KY/E-150, Martin Marietta Energy Systems, Inc., Paducah, KY, November.

APPENDIX A PLUME MAPS

A consolidated plume map is presented in Section 9 of this ASER. The original report, *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 1999 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, (BJC/PAD-169), contains many maps utilized to determine the consolidated plume map for the site.

APPENDIX B DATA SET

B.1 DEVELOPMENT OF DATA SET

B.1.1 DESCRIPTION OF MAPS

The maps generated for this report graphically portray TCE and ^{99}Tc concentrations in the RGA. For purposes of this report the RGA is defined as those sediments found between the elevations of 76.2 m (250 ft) and 97.5 m (320 ft) above mean sea level and bounded by the Porters Creek terrace to the south and the Ohio River to the north. The east and west boundaries of the study area are defined by Metropolis Lake Road and Bethel Church Road, respectively. The upper and lower boundaries were selected so that the shallowest and deepest portions of the RGA would be included. As a result, some of the groundwater samples in the data set may actually be from the upper continental recharge system or from the McNairy Formation. However, it is appropriate to include these samples since they serve as boundaries to the plumes and help define the lateral and vertical extents of contamination.

B.1.2 DESCRIPTION OF DATA SET

The data set used for this plume map revision contains groundwater data from two types of sample locations: monitoring wells whose screen mid-point is between elevations 76.2 m (250 ft) and 97.5 m (320 ft) above mean sea level and temporary borings in which a groundwater sample was collected from between the same two elevations. Only those wells and borings for which location coordinates, surface elevations, and screen or sample depths were available were included in the data set. As a result data from the following projects are not included in this interpretation:

- monitoring wells belonging to the Tennessee Valley Authority's Shawnee Steam Plant,
- residential water wells within the study area,
- temporary borings from the WAG 22 RI,
- temporary borings from the Northeast Plume Interim Remedial Action, and
- temporary borings from the WAG 3 RI.

This information is currently being gathered and will be included in the next revision as appropriate.

B.1.3 SELECTION OF DATA POINTS

To identify those wells and borings which fit the depth criteria, the OREIS database was queried for all water samples analyzed for TCE, ^{99}Tc, or beta activity. The sample interval for each collected sample was converted to elevation and filtered to exclude those samples outside the elevations used to define the RGA. For monitoring wells, the elevation of the mid-point of the well screen was used as the sample depth. The samples were then segregated into lower, middle, and upper RGA intervals, defined as elevations 76.2 to 89.9 m (250 to 295 ft), 89.9 to 93.0 m (295 to 305 ft), and 93.0 to 97.5 m (305 to 320 ft) above mean sea level, respectively. The interval for the lower RGA is larger than the upper or middle so that data from "channels" identified in various portions of the plant would be included in the interpretation. Once the sample points were assigned to one of the three intervals, base maps for each interval that showed only those wells and borings that collected a sample from that interval were printed.

B.1.4 SELECTION OF GROUNDWATER DATA

The groundwater data set consists of TCE concentrations, ^{99}Tc activities, or beta activities for those data points defined as RGA in this report. The data were selected from all groundwater data collected on or before December 31, 1999, and entered in OREIS by March 1, 2000. For monitoring well data, time versus concentration plots were created and trend lines developed. To normalize the data, these trend lines were used to determine the probable concentration of the well as of June 30, 1999. This value was then plotted on the base maps. For temporary borings, the actual analytical value was used. For borings with multiple samples within one interval, the highest concentration within the interval was selected and plotted on the base maps. Data from CY 1999 were given the highest priority, while data from earlier years were used in trending and identifying approximate boundaries with the oldest data being of least value in the interpretation.

B.1.5 MAPPING OF DATA

After all data were plotted on the base maps, the data were hand-contoured. Separate maps were made for both TCE and ^{99}Tc in the upper, middle and lower RGA intervals. The contour intervals for TCE and ^{99}Tc were as follows:

TCE	^{99}Tc
5 µg/L	25 pCi/L
100 µg/L	100 pCi/L
1000 µg/L	900 pCi/L
10,000 µg/L	3790 pCi/L
100,000 µg/L	10,000 pCi/L

The contour intervals for ^{99}Tc reflect in part detection limits (25 pCi/L) or regulatory benchmarks (900 and 3790 pCi/L). After contouring was completed, the maps were digitized and a composite map created by combining the three interval maps for TCE and ^{99}Tc.

The remaining tables of data sets and graphs in the report, *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 1999 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* (BJC/PAD-169), are available in the DOE Environmental Information Center.