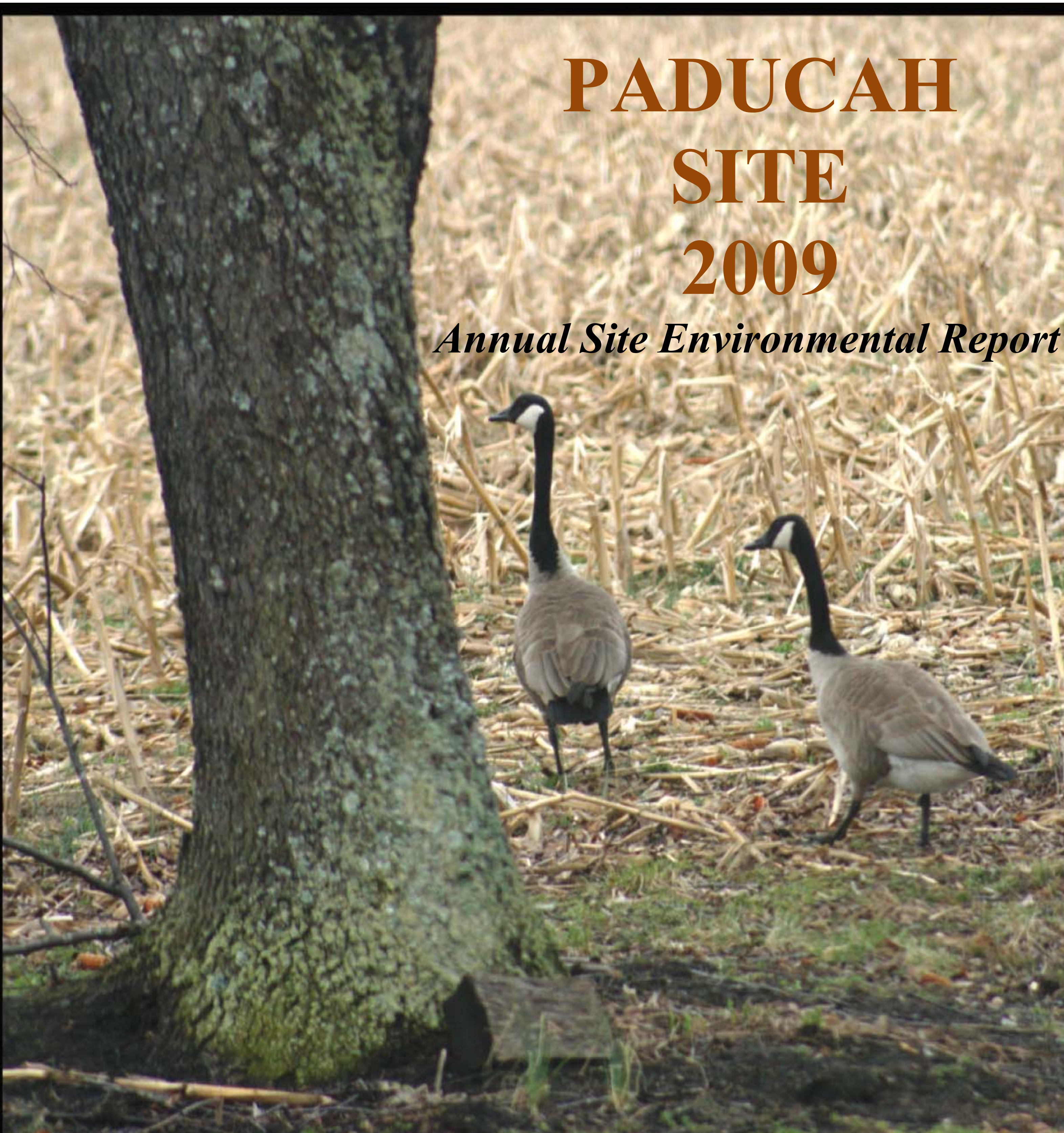
PAD-ENM-0053
Volume I

PADUCAH SITE 2009

Annual Site Environmental Report



Environmental Management

safety ❖ performance ❖ cleanup ❖ closure

Fractions and Multiples of Units

Multiple	Decimal Equivalent	Prefix	Symbol	Engineering Format
10^{6}	1,000,000	mega-	M	E+06
10^{3}	1,000	kilo-	k	E+03
10^{2}	100	hecto-	h	E+02
10	10	deka-	da	E+01
10^{-1}	0.1	deci-	d	E-01
10^{-2}	0.01	centi-	c	E-02
10^{-3}	0.001	milli-	m	E-03
10^{-6}	0.000001	micro-	µ	E-06
10^{-9}	0.000000001	nano-	n	E-09
10^{-12}	0.000000000001	pico-	P	E-12
10^{-15}	0.000000000000001	femto-	F	E-15
10^{-18}	0.000000000000000001	atto-	a	E-18

This report is intended to fulfill the requirements of U. S. Department of Energy Order 231.1A. The data and information contained in this report were collected in accordance with the Paducah Site Environmental Monitoring Plan (PRS 2009a; PRS 2009b) approved by DOE. This report is not intended to provide the results of all sampling conducted at the Paducah Site. Additional data collected for other site purposes, such as environmental restoration, remedial investigation reports, and waste management characterization sampling, are presented in other documents that have been prepared in accordance with applicable DOE guidance and/or federal or state laws.

PAD-ENM-0053
Volume I

Paducah Site

Annual Site Environmental Report for Calendar Year 2009

October 2010

Prepared for the
U.S. DEPARTMENT OF ENERGY
Office of Environmental Management

Prepared by
LATA ENVIRONMENTAL SERVICES OF KENTUCKY, LLC
managing the
Environmental Remediation Activities at the
Paducah Gaseous Diffusion Plant
under contract DE-AC30-10CC40020

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Acronyms and Abbreviations

ACM	asbestos-containing material
ACO	Administrative Order by Consent
AEC	Atomic Energy Commission
AIP	Agreement in Principle
AO	Agreed Order
ARRA	American Recovery and Reinvestment Act
ASER	Annual Site Environmental Report
ASTM	American Society of Testing and Materials
BGOU	Burial Grounds Operable Unit
BHHRA	Baseline Human Health Risk Assessment
BRA	Baseline Risk Assessment
CAA	Clean Air Act
CAB	Paducah Citizens Advisory Board
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
COE	U.S. Army Corps of Engineers
CSOU	Comprehensive Site Operable Unit
CWA	Clean Water Act
CX	categorical exclusion
CY	calendar year
D&D	decontamination and decommissioning
DCG	derived concentration guideline
DMSA	DOE Material Storage Area
DNAPL	dense nonaqueous-phase liquid
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOECAP	U.S. Department of Energy Consolidated Audit Program
DQO	data quality objective
DUF_6	depleted uranium hexafluoride
EA	environmental assessment
EDD	electronic data deliverable
EE/CA	engineering evaluation/cost analysis
EIC	Environmental Information Center
EIS	environmental impact statement
EM	environmental management
EMP	Environmental Monitoring Plan
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
FFA	Federal Facility Agreement
FFC Act	Federal Facilities Compliance Act
FFCA	Federal Facilities Compliance Agreement
FR	*Federal Register*
FS	feasibility study
FY	fiscal year
GDP	gaseous diffusion plant
GWOU	Groundwater Operable Unit
HAP	hazardous air pollutant
ICRP	International Commission on Radiological Protection

IRA	interim remedial action
ISO	International Organization for Standardization
KAR	*Kentucky Administrative Regulations*
KCHFS	Kentucky Cabinet for Health and Family Services
KDAQ	Kentucky Division for Air Quality
KDEP	Kentucky Department for Environmental Protection
KDOW	Kentucky Division of Water
KDWM	Kentucky Division of Waste Management
KPDES	Kentucky Pollutant Discharge Elimination System
KYREG	Kentucky regulations
LLW	low-level radioactive waste
LPAF	Liquid Pollution Abatement Facility
LRGA	Lower Regional Gravel Aquifer
MCL	maximum contaminant level
MGD	million gallons per day
MW	monitoring well
ND	not detected
NEPA	National Environmental Policy Act
NEPCS	Northeast Plume Containment System
NESHAP	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NOV	notice of violation
NPL	National Priorities List
NR	not reported
NRHP	National Register of Historic Places
NSDD	North-South Diversion Ditch
NWPGS	Northwest Plume Groundwater System
OREIS	Oak Ridge Environmental Information System
OS	outside
OU	operable unit
PCB	polychlorinated biphenyl
PEMS	Project Environmental Measurement Systems
PGDP	Paducah Gaseous Diffusion Plant
pH	hydrogen-ion concentration
PPE	personal protective equipment
PRS	Paducah Remediation Services, LLC
^{239}Pu	plutonium-239
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
RI	remedial investigation
ROD	Record of Decision
SDWA	Safe Drinking Water Act
SERA	Screening Ecological Risk Assessment
SI	site investigation
SMO	Sample Management Office
SMP	Site Management Plan
SOW	statement of work
STP	Site Treatment Plan
SWMU	solid waste management unit

^{99}Tc	technetium-99
TCE	trichloroethene
TLD	thermoluminescent dosimeter
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
TTL	Target Treatment Level
TVA	Tennessee Valley Authority
UCRS	Upper Continental Recharge System
UDS	Uranium Disposition Services, LLC
UE	uranium enrichment
UF_6	uranium hexafluoride
URGA	Upper Regional Gravel Aquifer
USEC	United States Enrichment Corporation
UST	underground storage tank
VOA	volatile organic analyte
VOC	volatile organic compound
WKWMA	West Kentucky Wildlife Management Area
WMP	Watershed Monitoring Program
WM/PP	waste minimization/pollution prevention

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. This report presents the results from the various environmental monitoring programs and activities carried out during the year. This *Paducah Site Annual Site Environmental Report for Calendar Year 2009* was prepared to fulfill DOE requirements. This report is a public document that is distributed to government regulators, businesses, special interest groups, and members of the public.

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 in a clear and concise manner. The editors of this report encourage comments in order to better address the needs of our readers in future site environmental reports. Please send comments to the following address:

U.S. Department of Energy
Portsmouth/Paducah Project Office
1017 Majestic Drive, Suite 200
Lexington, Kentucky 40513

Executive Summary

The 2009 Annual Site Environmental Report (ASER) for the Paducah Gaseous Diffusion Plant (PGDP) has been prepared to inform the public, regulators, stakeholders, and other interested parties of PGDP environmental performance. The ASER summarizes the compliance status with all applicable federal, state, and local regulations, summarizes results of environmental monitoring, discusses potential radiation doses to the public residing in the vicinity of the PGDP site, and describes quality assurance methods used to ensure confidence in monitoring data. This report is published annually for the U.S. Department of Energy (DOE) in accordance with the following DOE Orders: DOE Order 450.1A, Environmental Protection Program; DOE Order 231.1A, Environment, Safety, and Health Reporting; and DOE Order 5400.5 Radiation Protection of the Public and the Environment.

DOE Order 450.1A requires implementation of sound stewardship practices that protect air, water, land, and cultural and ecological resources impacted by DOE operations. This objective is to be accomplished by implementing Environmental Management System (EMS). DOE defines EMS as a continuous cycle of planning, implementing, evaluating, and improving processes and actions to achieve environmental missions and goals. The PGDP's EMS is designed to integrate environmental protection, environmental compliance, pollution prevention, and continual improvement into work planning and execution throughout all work areas and conforms to the five core elements of the International Organization for Standardization (ISO) EMS standard (ISO 14001). The Paducah site performs environmental surveillance monitoring which is the collection and analysis of samples or direct measurements of air, water, soil, biota, and other media from DOE sites and their environment for the purpose of determining compliance with applicable standards and permit requirements, assessing radiation exposures to members of the public, and assessing the effects, if any, on the local environment.

DOE Order 231.1A requires the timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues as required by law or regulations or as needed to ensure that the DOE is kept fully informed on a timely basis about events that could adversely affect the health and safety of the public or the workers, the environment, the DOE mission, or the credibility of DOE.

DOE Order 5400.5 establishes a radiation protection standard of 100 mrem per year from all exposure pathways to members of the public. This order defines “public dose” as the dose received by member(s) of the public from exposure to radiation and to radioactive material released by a DOE facility or operation, whether the exposure is within a DOE site boundary or off-site. It does not include doses received from occupational exposures, doses received from naturally occurring “background” radiation, doses received by a patient from medical procedures, or doses received from consumer products. This standard requires that exposure to members of the public to radiation sources as a consequence of all routine DOE activities shall not cause, in a year, an effective dose equivalent greater than 100 mrem. The maximum dose the public may receive from drinking water, as specified by the Safe Drinking Water Act, is 4 mrem per year.

In 2009, work continued under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in order to ensure that environmental impacts at the site are investigated and remediated. Site cleanup activities will occur in a sequenced approach consisting of (1) pre-shutdown scope, (2) post-shutdown scope, and (3) Comprehensive Site Operable Unit (CSOU) scope. The pre-shutdown scope with media-specific operable units (OUs) initiate prior to shutdown of the operating gaseous diffusion plant (GDP) (i.e., Pre- GDP Shutdown Activities). The source areas for the pre-GDP shutdown scope have been grouped into these media-specific OUs.

- Groundwater OU
- Surface Water OU
- Soils OU
- Burial Grounds OU
- Decontamination and Decommissioning (D&D) OU

Once the GDP ceases operation and a decision has been made to proceed with D&D of the GDP, a series of post-GDP shutdown activities will be implemented. The final CSOU evaluation will occur following plant shutdown and completion of D&D of the GDP, D&D of the Depleted Uranium Hexafluoride Conversion Plant, and completion of post-shutdown cleanup of each of the specific OUs.

In addition to the operable units identified, the Kentucky Department for Environmental Protection issued a Hazardous Waste Facility Permit to address four permitted storage and treatment facilities and one closed hazardous waste landfill. PGDP also was issued a solid waste permit that covers two closed landfills and one operating solid waste contained landfill. The Kentucky Division of Water has issued two permits to PGDP, a Kentucky Pollutant Discharge Elimination System permit and a water withdrawal permit.

Compliance with environmental regulations and with DOE orders related to environmental protection provides assurance that on-site processes do not impact the public or environment. Information provided in the 2009 ASER documents this compliance. During calendar year (CY) 2009, Paducah Remediation Services, LLC, (PRS) was responsible for ensuring compliance with all applicable laws, regulations, and other requirements, as defined in the contract DE-AC30-06EW05001. PRS performed environmental remediation work at PGDP. The work scope included activities such as performing groundwater and soil remedial actions, groundwater and surface water monitoring, removing legacy waste, decontaminating and decommissioning facilities, and operating on-site waste storage facilities, as well as surveillance and maintenance activities involving hazardous, radioactive, and mixed wastes. During 2009, PGDP received three Notices of Violation (NOVs) from the Commonwealth of Kentucky for alleged violations of permit requirements, one of which has been fully rescinded. A second NOV was rescinded with the exception of an alleged exceedance of oil and grease at Outfall 017. The one remaining NOV dealt with the C-746-U Landfill (solid waste contained landfill) for improper use of cover material, equipment checks, and waste staging. PGDP since has completed corrective measures to address these issues.

Environmental monitoring is conducted for PGDP and surrounding areas. The site's radioactive and chemical discharges to air and water are discussed in this document, and data gathered is summarized in Volume 2 of this ASER. For CY 2009, exposure pathways potentially contributing to radiological dose include ingestion of surface water, ingestion of sediments, direct radiation, and atmospheric release. The worst-case combined internal and external dose to an individual member of the public was calculated at 0.46 mrem. This level is well below the DOE annual dose limit of 100 mrem/year to members of the public. 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, sediment, soil, vegetation, terrestrial wildlife, and other aquatic life. Surveillance results for 2009 were similar to previous years. During CY 2009, 63 additional monitoring wells were installed to supply additional groundwater characterization to address groundwater contamination.

In December 2009, an allegation was made that between the years 1980 and 1981 soils from the PGDP had been used as backfill at the Heath Elementary school. Based on this allegation, site characterization sampling was completed. The sampling results indicate that there is no indication of PGDP process related material present on the Heath Elementary School property.

The PGDP maintains a Quality Assurance/Quality Control Program to verify the integrity of data generated within the Environmental Monitoring Program. Sampling methods, instruments, locations, schedules, and other sampling and monitoring criteria are based on applicable guidelines from various established authorities.

It should be noted that, during CY 2009, the designated DOE contractor for the PGDP Site was Paducah Remediation Services, LLC. At the time this document was published, the contractor had changed to LATA Environmental Services of Kentucky, LLC.

1 Introduction

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), a private company. DOE maintains responsibility for the environmental restoration, legacy waste management, nonleased facilities management, uranium hexafluoride (UF_6) cylinder management, and decontamination and decommissioning (D&D)/DOE Material Storage Area (DMSA) programs. DOE also implements 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 (CY) 2009 environmental management (EM) 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 monitoring activities.***

DOE requires that environmental monitoring be conducted and documented for all of its facilities under the purview of DOE Order 231.1A, *Environment, Safety, and Health Reporting*. Several other laws, regulations, and DOE directives require compliance with environmental standards. The purpose of this Annual Site Environmental Report (ASER) is to summarize CY 2009 EM activities at the Paducah Site, including effluent monitoring, environmental surveillance, and environmental compliance status, and to highlight significant site program efforts. Paducah Site programs are coordinated by DOE's remediation contractor, Paducah Remediation Services, LLC (PRS). References in this report to the Paducah Site generally mean the property, programs, and facilities at or near PGDP for which DOE has ultimate responsibility.

Environmental monitoring consists of the following 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 consisting of ambient air, surface water, groundwater, soil, 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 constituents, and various physical properties.

The overall goals for DOE/EM are to protect site personnel, the environment, and Paducah Site neighbors; and to maintain full compliance with all current environmental regulations. The current environmental strategy is to prevent noncompliance, to identify any current compliance issues, and to develop a system for resolution. The long-range goal of DOE/EM 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 PGDP was used for agricultural purposes. Numerous small farms produced various grain crops, provided pasture for livestock, and included large fruit orchards. During World War II, a 16,126-acre tract was assembled for construction of the Kentucky Ordnance Works, a trinitrotoluene production facility, which subsequently was operated by the Atlas Powder Company until the end of the war. At that time, 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 (DOD) and DOE's predecessor, the Atomic Energy Commission (AEC), 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 initially were selected as candidate areas. In October 1950, as a result of joint recommendations from DOD, U.S. Department of State, and AEC, President Harry S. Truman directed AEC to expand further 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, AEC approved the Paducah Site for uranium enrichment (UE) operations and formally requested the Department of the Army to transfer the site from the General Services Administration to AEC. Although construction of PGDP was not complete until 1954, production of enriched uranium began in 1952.

The plant's mission of UE has continued unchanged, and the original facilities still are in operation, albeit with substantial upgrading and refurbishment. Of the 7,566 acres acquired by the AEC, 1,361 acres subsequently were transferred to the Tennessee Valley Authority (TVA) (Shawnee Steam Plant site), and 2,781 acres were conveyed to the Commonwealth of Kentucky for wildlife conservation and for recreational purposes [West Kentucky Wildlife Management Area (WKWMA)]. DOE's current holdings at the Paducah Site total 3,556 acres, including easements.

At Paducah's UE 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 resumed in 1969 and continued through 1976. In 1976, the practice of recycling uranium feed material from nuclear reactors was halted and never resumed. During the recycling time periods, Paducah received approximately 100,000 tons of 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 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 and in waste products.

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

Description of Site Locale

Location

The Paducah Site is located in a generally rural area of McCracken County, Kentucky (population approximately 67,000). PGDP is an active uranium enrichment facility consisting of a diffusion cascade and extensive support facilities. The cascade, including product and tails withdrawal, is housed in six large process buildings. The plant is located on a reservation consisting of approximately 3,556 acres in western McCracken County, 10 miles west of Paducah, Kentucky, (population approximately 26,000), and 3.5 miles south of the Ohio River (Figure 1.1). The facility is on approximately 1,350 acres with controlled access. Roughly, 650 acres of the reservation are enclosed within a fenced security area. An uninhabited buffer zone of at least 400 yd surrounds the entire fenced area. During World War II, the Kentucky Ordnance Works was operated in an area southwest of the plant on what is now a wildlife management area.

Three small communities are located within 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 Regional Airport, approximately 5 miles to the southeast. The population within a 50-mile radius of PGDP is about 500,000. Within a 10-mile radius of PGDP, the population is about 66,000 (DOC 2000).

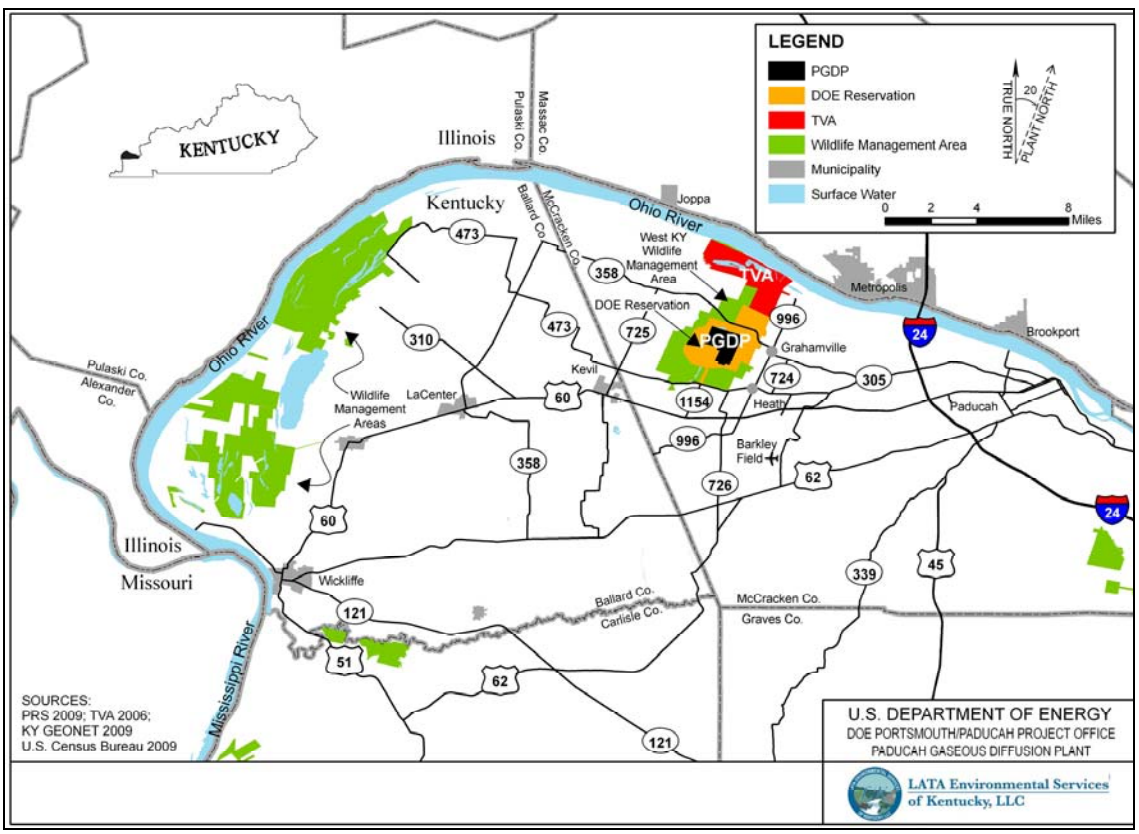

Figure 1.1. Location of the Paducah Site

Climate

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

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 15 miles upstream of the site, and the confluence of the Ohio River with the Mississippi River is about 35 miles downstream. PGDP is located on a local drainage divide. Surface water from the east side of the plant flows east-northeast toward Little Bayou Creek, and surface water from the west side of the plant flows west-northwest toward Bayou Creek. Bayou Creek is a perennial stream that flows toward the Ohio River along a 9-mile course. Little Bayou Creek is an intermittent stream that flows north toward the Ohio River along a 7-mile course. The two creeks converge 3 miles north of the plant before emptying into the Ohio River.

Flooding in the area is associated with Bayou Creek, Little Bayou Creek, and the Ohio River. Maps of the calculated 100-year flood elevations show that all three drainage systems have 100-year floodplains located within the DOE boundary at PGDP, but not within the industrialized area of PGDP. These 100-year floodplains range from approximately 340 to 380 ft above mean sea level. Plant elevations range from about 370 to 385 ft above mean sea level [U.S. Army Corps of Engineers (COE) 1994].

Wetlands

More than 1,100 separate wetlands, totaling over 1,600 acres, were found in a study area of about 12,000 acres in and around the Paducah Site (COE 1994; CDM 1994). More than 60 percent of the total wetland area is forested.

Soils and Hydrogeology

Soils of the area are predominantly silty loams that are poorly drained, acidic, and have little organic content.

The local groundwater flow system at the Paducah Site contains the following four major components (listed from shallowest to deepest): (1) the Terrace Gravel, (2) the Upper Continental Recharge System (UCRS), (3) the Regional Gravel Aquifer (RGA), and (4) the McNairy flow system.

The Terrace Gravel consists 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 clay 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 coarse-grained sediments in its upper portions that are adjacent to the base of the upper continental deposits, sand and gravel facies in the middle, and gravel and coarse sand portions that are directly adjacent to the upper McNairy. Near the Ohio River, alluvium lies adjacent to the upper RGA. These deposits have an average thickness of 30 ft and can be more than 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 is composed of interbedded and interlensing sand, silt, and clay. Near PGDP, the McNairy Formation can be subdivided into three members: (1) a 60-ft thick sand-dominant lower member; (2) a 100- to 130-ft thick middle member, composed predominately of silty and clayey fine sand; and (3) a 30- to 50-ft thick upper member consisting of interbedded sands, silts, clays, and occasional gravel. Sand facies account for 40 to 50 percent of the total formation thickness of approximately 225 ft.

Groundwater flow originates south of the Paducah Site within Eocene sands and the Terrace Gravel. Groundwater within the Terrace Gravel discharges to local streams and recharges the RGA. Groundwater flow through the UCRS predominantly is downward, also recharging the RGA. From the plant site, groundwater generally flows northward in the RGA toward the Ohio River, which is 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 mowed periodically or burned to maintain early successional vegetation, which is dominated by members of the *Compositae* family and various grasses. 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 1991). The undergrowth varies depending on the location of the woodlands. Wooded areas near maintained grasslands have an undergrowth dominated by grasses. Other communities 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 1991). The undergrowth here varies, with limited undergrowth 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. A list of representative species is provided in the reference, CH2M Hill 1991, given in the reference section. Additionally, the Ohio River, which is 3 miles north of the Paducah Site, serves as a major flyway for migratory waterfowl (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). Updated information is obtained on a regular basis from federal and Commonwealth of Kentucky sources. Currently, potential habitat for 11 species of federal concern exists in the study area. Nine of these species are listed as "endangered" under the Endangered Species Act of 1973 and two are listed as "candidate" (Section 2, Table 2.2). While there are potential habitats for endangered species on DOE property, none of the federally listed or candidate species has been found on DOE property at the Paducah Site.

Site Program Missions

The following two major programs are operated by DOE at the Paducah Site: (1) EM and (2) Uranium Programs. Environmental Restoration, Materials Disposition, and D&D are projects under the EM Program. The mission of the Environmental Restoration Project is to ensure that releases from past operations at the Paducah Site are investigated and that appropriate response action is taken for protection of human health and the environment in accordance with the Federal Facility Agreement (FFA) (EPA 1998). The mission of the Materials Disposition Project is to characterize and dispose of the legacy and newly generated waste stored on-site, including DMSAs, in compliance with the October 2003 Agreed Order (AO) between DOE and the Kentucky Division of Waste Management (KDWM) and other regulatory requirements. The major mission of the D&D Project is to D&D excess buildings (i.e., inactive with no reuse potential) to minimize or eliminate the possible health and environmental hazards caused by the uncontrolled release of hazardous substances from contaminated structures. The major missions of the Uranium Program are to maintain safe, compliant storage of the DOE depleted UF_6 (DUF_6) inventory until final disposition and to manage facilities and grounds not leased to USEC. The environmental monitoring summarized in this report supports all DOE programs/projects.

2 Compliance Summary

Abstract

The policy of DOE and its contractors and subcontractors at the Paducah Site is to conduct operations safely and minimize or eliminate the adverse impact of operations on the environment. Protection of the environment is considered a responsibility of paramount importance. The Paducah Site maintains an environmental compliance program aimed at satisfying all applicable requirements and protecting human health and the environment.

Introduction

Commonwealth of Kentucky and federal agencies, including DOE, are responsible for enforcing the environmental regulations at the Paducah Site. Principal regulating agencies are the U.S. Environmental Protection Agency (EPA), Region 4, 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 most instances, EPA has delegated regulatory authority to KDEP when the Kentucky program meets or exceeds EPA requirements. Table 2.1 provides a summary of the Paducah Site environmental permits maintained by DOE in CY 2009.

Table 2.1. Permits Maintained by DOE for the Paducah Site for CY 2009

Permit Type	Issued By	Permit Number	Issued To
State Agency Interest ID# 3059			
Water			
Kentucky Pollutant Discharge Elimination System	KDOW	KY0004049	DOE/PRS/UDS
Water Withdrawal Permit	KDOW	1345	DOE
Solid Waste			
Residential Landfill (closed)	KDWM	SW07300014	DOE/PRS
Inert Landfill (closed)	KDWM	SW07300015	DOE/PRS
Solid Waste Contained Landfill (construction/operation)	KDWM	SW07300045	DOE/PRS
RCRA/Toxic Substances Control Act			
Hazardous Waste Facility Permit	KDWM	KY8-890-008-982	DOE/PRS

KDOW = Kentucky Division of Water
RCRA = Resource, Conservation, and Recovery Act
UDS = Uranium Disposition Services, LLC

Under the lease agreement with USEC, DOE retained responsibility for the site Environmental Restoration Program; the Enrichment Facilities Program; the Legacy Waste Management Program, including all waste inventories predating July 1, 1993; and wastes generated by subsequent DOE activities. DOE, PRS, and Uranium Disposition Services, LLC, (UDS) are co-permittees on the Kentucky Pollutant Discharge Elimination System (KPDES) compliance permit. DOE is responsible for all outfalls addressed by this permit. UDS responsibility is limited to Outfall 017 only. PRS is responsible for the remaining Outfalls (001, 015, 019, and 020). DOE also has retained responsibility 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. DOE is the owner, and DOE and its contractor are co-operators for Resource Conservation and Recovery Act (RCRA)-permitted facilities and are responsible for compliance with the RCRA permit.

Resource Conservation and Recovery Act

Regulatory standards for the characterization, treatment, storage, and disposal of solid and hazardous waste are established by RCRA. Waste generators must follow specific requirements outlined in RCRA regulations for handling solid and hazardous wastes. Owners and operators of hazardous waste treatment, storage, and disposal facilities are required to obtain operating and/or post-closure permits for waste treatment, storage, and disposal activities. The Paducah Site generates solid waste, hazardous waste, and mixed waste (i.e., hazardous waste mixed with radionuclides) and operates four permitted hazardous waste storage and treatment facilities. The closed C-404 Hazardous Waste Landfill also is managed under requirements of the RCRA regulations and permit.

Resource Conservation and Recovery Act Hazardous Waste Permit

Part A and Part B permit applications of RCRA for storage and treatment of hazardous wastes initially were submitted for the Paducah Site in the late 1980s. At that time, EPA had authorized the Commonwealth of Kentucky to administer exclusively the RCRA-based program for treatment, storage, and disposal units, but had not given the authorization to administer 1984 Hazardous and Solid Waste Amendments provisions.

The current hazardous waste management facility permit was issued to DOE on September 30, 2004. The permit became effective on October 31, 2004, and is valid until October 31, 2014. The Part B permit application was modified on April 24, 2006, to identify PRS as an operator.

Resource Conservation and Recovery Act Notices of Violation

DOE received one RCRA notice of violation (NOV) during 2009. KDWM issued an NOV dated September 29, 2009, requesting additional information for certain waste characterization and manifest issues identified during an earlier inspection. DOE responded with additional documentation on October 30, 2009. KDWM determined the response to be adequate, and the NOV subsequently was rescinded on January 12, 2010.

2003 Agreed Order with Commonwealth of Kentucky

In October 2003, DOE and the Commonwealth of Kentucky entered into an Agreed Order (AO) to address alleged violations at PGDP. Agreed Order DWM-31434-042, DAQ-31740-030, and DOW-26141-042, hereinafter are referred to as the 2003 AO. The main focus of the 2003 AO established requirements of the DMSA Characterization/Remediation Plan, which included a schedule of enforceable milestones. In order to establish this schedule, the DMSAs were divided into priority levels.

The main program components in the 2003 AO pertained to RCRA-listed hazardous waste and DMSAs. Each DMSA was prioritized for removal based on the potential risk to plant workers and the environment, with "A" representing greatest potential risk, "B" representing medium potential risk, and "C" representing lowest potential risk. As required by the 2003 AO, all requirements for the highest priority DMSAs, Priority A, were met in 2004, and all of the requirements for the second-highest priority, Priority B, were met in 2006. Priority C DMSA requirements were met before the milestone completion date of September 30, 2009. To date, the following accomplishments have been met.

- DOE has completed characterization of DMSAs in accordance with the schedule outlined in the AO.

- Twenty-five closure plans related to DMSAs were submitted to KDWM in 2009. Sixty-seven closure plans have been submitted to KDWM since the onset of the program.

Modifications to the Hazardous Waste Management Facility Permit

There were no modifications to the Hazardous Waste Management Facility Permit in 2009.

Federal Facility Compliance Act—Site Treatment Plan

The Federal Facilities Compliance Act (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. It also contained provisions for the development of site treatment plans (STPs) for the treatment of DOE mixed waste and for the approval of such plans by the Commonwealth of Kentucky. As a result of the complex issues and problems associated with the treatment of mixed chemical hazardous and radioactive waste (mixed waste), DOE and KDEP signed, after consideration of stakeholder input, an AO/STP on September 10, 1997. The STP facilitates compliance with the FFC Act. A series of mixed waste treatment milestones are detailed in the STP. The STP also requires that DOE consider waste minimization in all projects and processes. The waste minimization program is discussed in Section 3.

Solid Waste Management

The PGDP disposes of a portion of its solid waste at its 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. A new operation permit for the C-746-U Landfill was received from KDWM in November 2006. No permit modifications were requested or issued in 2009. During 2009, the landfill received 2201.57 tons of waste from varying Paducah Site operations.

The office waste generated by DOE and its contractors at the plant site is taken off-site for disposal. Only office waste generated at the C-746-U Landfill itself is disposed at the landfill. Waste Path Services, LLC, in Calvert City, Kentucky, provides off-site disposal services of the office waste from the Paducah Site. The City of Kevil picks up the office waste from the office complexes in Kevil, Kentucky that house many of the administrative personnel who support activities at the site.

DOE did not receive any NOVs during 2009 for the inactive C-746-S&T Landfills. KDWM issued an NOV dated May 13, 2009, for the C-746-U Landfill for improper use of cover material, equipment checks, and waste staging identified during the inspection on May 4, 2009. DOE provided evidence of completion of remedial measures required by the NOV on August 10, 2009. KDWM responded in a letter dated August 27, 2009, indicating that DOE had taken sufficient action to address the alleged violations cited in the NOV.

Underground Storage Tanks

Underground storage tank (UST) systems at the Paducah Site were used to store petroleum products such as gasoline, diesel fuel, and waste oil. These USTs are regulated under RCRA Subtitle I [40 *Code of Federal Regulations* (*CFR*) Part 280] and Kentucky UST regulations [401 *Kentucky Administrative Regulations* (*KAR*) Chapter 42].

Of the 18 USTs that have been reported to KDWM only 2 are still operational, 14 have been closed in accordance with approved closure plans, and 2 were determined not to exist. Both of the operational USTs operate under USEC's responsibility. No additional actions were taken in 2009.

Comprehensive Environmental Response, Compensation, and Liability Act

DOE and EPA Region 4 entered into an Administrative Order by Consent (ACO) in August 1988 under Sections 104 and 106 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The ACO was in response to the off-site groundwater contamination detected at the Paducah Site in July 1988.

On May 31, 1994, the Paducah Site was placed on the EPA National Priorities List (NPL), which is a list of sites across the nation designated by EPA as having the highest priority for site remediation. The EPA uses the Hazard Ranking System to determine which sites should be included on the NPL.

Section 120 of CERCLA requires federal agencies with facilities on the NPL to enter into an FFA with the EPA. The FFA, which was signed February 13, 1998, by DOE, EPA, and KDEP, established a decision-making process for remediation of the Paducah Site and coordinates CERCLA remedial action requirements with RCRA corrective action requirements. The FFA parties—DOE, EPA, and KDEP—agreed to terminate the CERCLA ACO because those activities could be continued under the FFA. According to the FFA, DOE is required to submit an annual Site Management Plan (SMP) to EPA and KDEP. The SMP 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 to include any new strategic approaches.

Comprehensive Environmental Response, Compensation, and Liability Act Reportable Quantities

In 2009, there were no spills of CERCLA-regulated substances above CERCLA reporting requirements.

National Environmental Policy Act

An evaluation of the potential environmental impact of certain proposed federal activities is required by the National Environmental Policy Act (NEPA). In addition, an examination of alternatives to certain proposed actions is required. Compliance with NEPA, as administered by DOE's NEPA Implementing Procedures (10 *CFR* § 1021) and the 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 non-CERCLA actions and determines if any proposal requires preparation of an environmental impact statement (EIS), an environmental assessment (EA), or is a categorical exclusion (CX) from preparation of either an EIS or an EA. The Paducah Site maintains records of all NEPA reviews.

Numerous minor activities were within the scope of the previously approved CXs for routine maintenance, small-scale facility modifications, and site characterization. The DOE Paducah Site Office and the Portsmouth/Paducah Project Office NEPA compliance officer approve and monitor the internal applications of previously approved CX determinations.

In accordance with the 1994 DOE Secretarial Policy Statement on NEPA, preparation of separate NEPA documents for environmental restoration activities conducted under CERCLA no longer is required. Instead, the DOE CERCLA process incorporates "NEPA values." The NEPA values are environmental issues that affect the quality of the human environment. Documentation of NEPA values in CERCLA documents allows the decision makers to consider the potential effects of proposed actions on the human environment. Actions conducted under CERCLA are discussed in Section 3 of this report.

National Historic Preservation Act

The National Historic Preservation Act of 1966 (NHPA) is the primary law governing a federal agency's responsibility for identifying and protecting historic properties [cultural resources included in or eligible for inclusion in the National Register of Historic Places (NRHP)]. Historic properties include buildings of historic significance and archeological sites. PGDP buildings were assessed in the *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (BJC/PAD-688/R1, hereinafter referred to as the Cultural Resources Management Plan), March 2006. Archeological resources will be addressed as undisturbed land is developed for site use.

The Cultural Resources Management Plan identified an NRHP-eligible historic district at the facility. The PGDP Historic District contains 101 contributing properties and is eligible for the NRHP under National Register Criterion A for its military significance during the Cold War and for its role in commercial nuclear power development. The PGDP historic district encompasses the area of the process buildings; the switchyards; the C-100 Administration Building; cooling towers and pump houses; security facilities; water treatment facilities; storage tanks; and the support, maintenance, and warehouse buildings. A map and the rationale for designating the area as such are included in the Cultural Resources Management Plan.

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 EMS or the CERCLA process, 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 and Kentucky Department for Fish and Wildlife Resources prior to implementing a proposed project.

Table 2.2 includes 11 federally listed, proposed, or candidate species that have been identified as potentially occurring at or near the Paducah Site. No DOE project at the Paducah Site during 2009 impacted any of these 11 species or their potential habitats.

Table 2.2. Federally Listed, Proposed, and Candidate Species Potentially Occurring within the Paducah Site Study Area in CY 2009[a]

Common Name	Scientific Name	Endangered Species Act Status
Indiana Bat[b]	*Myotis sodalis*	Listed Endangered
Fanshell	*Cyprogenia Stegaria*	Listed Endangered
Pink Mucket	*Lampsilis abrupta*	Listed Endangered
Ring Pink	*Obovaria retusa*	Listed Endangered
Orangefoot Pimpleback	*Plethobasus cooperianus*	Listed Endangered
Clubshell	*Pleurobema Clava*	Listed Endangered
Rough Pigtoe	*Pleurobema Plenum*	Listed Endangered
Fat Pocketbook	*Potamilus capax*	Listed Endangered
Spectaclecase	*Cumberlandia Monodonta*	Listed Candidate
Sheepnose	*Plethobasus Cyphyus*	Listed Candidate
Interior Least Tern	*Sterna antillarum athalassos*	Listed Endangered

[a] All of the listed species are identified as a Endangered, Threatened, or Candidate Species known or with the potential to be located within McCracken County, KY, by the U.S. Fish & Wildlife Service (July 30, 2008). Note that the area encompasses all of McCracken County not just the DOE Reservation. None of these species have 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.
[b] Specimens of the Indiana bat were netted, identified, measured, and released on WKWMA property in 1991 and 1999.

Floodplain/Wetlands Environmental Review Requirements

Title 10 *CFR* Part 1022, establishes procedures for compliance with Executive Order 11988, "Floodplain Management," and Executive Order 11990, "Protection of Wetlands."

In 2009, no floodplain or wetlands assessments were prepared or approved. Also, no floodplain or wetlands notices of involvement were published in the *Federal Register (FR)* for the Paducah Site. In addition, DOE did not apply for any individual permits from COE or for any water quality certifications from the Commonwealth of Kentucky. DOE activities did not result in significant impacts to floodplains or wetlands at the Paducah Site in 2009.

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 the following four major programs for control of water pollution:

(1) Regulating point-source discharges into waters of the United States;
(2) Controlling and preventing spills of oil and hazardous substances;
(3) Regulating discharges of dredge and fill materials into "waters of the United States"; and
(4) Providing financial assistance for construction of publicly owned sewage treatment works.

The Paducah Site is affected primarily by the regulations for point source discharges regulated under the KPDES permit.

Kentucky Pollutant Discharge Elimination System Permit

The CWA applies to all nonradiological DOE discharges to waters of the United States. At the Paducah Site, the regulations are applied through issuance of a KPDES permit for effluent discharges to Bayou Creek and Little Bayou Creek. KDOW issued KPDES Permit No. KY0004049 to the Paducah Site. This permit became effective November 1, 2006, and is enforced by KDOW. A modification to add outfall 020 to the KPDES Permit became effective on December 1, 2009. The modified KPDES permit includes the following five outfalls: 001, 015, 017, 019, and 020. The KPDES permit calls for monitoring as an indicator of discharge related effects in the receiving streams. The permit will expire on October 31, 2011.

Following the issuance of the permit in 2006, several parties petitioned KDOW for a hearing on the permit. An Order to Mediate was issued by the Kentucky Environmental and Public Protection Cabinet (now named the Kentucky Energy and Environment Cabinet).

An AO settled all parties' disputes with the permit on December 7, 2007. A revised KPDES permit incorporating the changes set forth in the AO was issued on November 4, 2009, to be effective December 1, 2009. This modified permit also added an additional outfall (020) to the monitoring locations for separate tracking and monitoring for treated leachate discharges from the C-746-U and C-746-S Landfills.

On June 4, 2009, the Enforcement Branch of the KDOW issued an NOV for alleged violations related to the KPDES permit that occurred in October 2008, February 2009, and March 2009.

The NOV alleged the following violations to the Paducah KPDES permit.

- Outfall 015 exceeded the total suspended solids (TSS) limits during the month of March of 2009. KDOW rescinded the NOV provision relative to TSS on June 26, 2009.

- KPDES Outfall 017 exceeded the total recoverable zinc limits during the month of February of 2009. KDOW rescinded the NOV provision relative to total recoverable zinc on June 26, 2009.

- In October 2008, the discharge from Outfall 017 had a 30-day average of 11 mg/L of oils and grease, which exceeded the permit limit of 10 mg/L. KDOW issued an NOV for this exceedance on June 4, 2009. Immediate investigations of the site conditions for October 2008 revealed no obvious direct cause for the reported analytical result, and there had been no spills or releases. The most probable explanation would be parking lot and roadway runoff from vehicles and runoff from a newly constructed asphalt parking lot serving the DUF_6 facility. A Corrective Action Plan was submitted to KDOW on July 7, 2009, closing the NOV.

Toxic Substances Control Act

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

Polychlorinated Biphenyls

The Paducah Site complies with polychlorinated biphenyl (PCB) regulations (40 *CFR* § 761) and the TSCA-UE-Federal Facilities Compliance Agreement (FFCA). The major activities performed in 2009 to ensure compliance included the following: maintaining compliant storage of PCB waste and PCB-contaminated wastewater; shipping PCB waste for treatment and disposal; treatment and discharge of PCB-contaminated wastewater; maintaining the PCB troughing system in PGDP buildings; and reporting and record keeping.

The TSCA-UE-FFCA between EPA and DOE was signed in February 1992. Under this agreement, action plans have been developed and implemented for removal and disposal of large volumes of PCB material at the Paducah Site. Table 2.3 shows a summary of PCB equipment in service at the Paducah Site at the end of 2009. These items are utilized in USEC operations.

Table 2.3. Summary of PCB Equipment in Service at the End of CY 2009

Type	Number in Service	Volume (gal)	PCBs (kg)
PCB Transformers	67	96,410	283,385.4
PCB Contaminated Transformers	9	2,299	0.95
PCB Contaminated Electrical Equipment	7	2,094	1.14
PCB Capacitors	386	1,156	7,077

The PCB Annual Document 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 TSCA-UE-FFCA milestones for 2009 were completed. During CY 2009, 401 containers of solid and liquid PCB remediation wastes, lab wastes, bulk product wastes, and liquid wastes, weighing approximately 290,277 kg, were shipped for treatment and/or landfill disposal at Energy*Solutions* in Clive, Utah, and liquids were shipped to Diversified Scientific Services, Inc., a subsidiary of Perma-Fix in Kingston, Tennessee.

The facilities operated by USEC utilize equipment that contain PCB capacitors as well as transformers, electrical equipment, and other miscellaneous PCB equipment. Both radioactive and nonradioactive PCB wastes are stored on-site in units that meet TSCA and/or TSCA-UE-FFCA compliance requirements, as applicable. Nonradioactive PCBs are transported off-site to EPA-approved facilities for disposal.

Radioactively contaminated PCB wastes are authorized by the TSCA-UE-FFCA for long-term on-site storage at the Paducah Site (i.e., beyond two years). Technology for the treatment and/or disposal of radioactively contaminated PCB wastes is being evaluated.

Emergency Planning and Community Right-to-Know Act

Also referred to as Title III of the Superfund Amendments and Reauthorization Act, the Emergency Planning and Community Right-to-Know Act (EPCRA) requires reporting of emergency planning information, hazardous chemical inventories, and releases to the environment.

EPCRA's primary purpose is to inform communities and citizens of chemical hazards in their areas. In order to ensure proper and immediate responses to potential chemical hazards, EPCRA Section 304 requires facilities to notify State Emergency Response Commissions and Local Emergency Planning Committees of releases of hazardous substances and extremely hazardous substances when the release equals or exceeds the reportable quantity. Sections 311 and 312 of EPCRA require businesses to report the locations and quantities of chemicals stored on-site to state and local governments in order to help communities prepare to respond to chemical spills and similar emergencies. EPCRA Section 313 requires EPA and the states to collect data annually on releases and transfers of certain toxic chemicals from industrial facilities, and make the data available to the public.

The Paducah Site did not have any releases that were subject to EPCRA Section 304 notification requirements during 2009. No EPCRA Section 311 notifications were required in 2009. The EPCRA Section 312 Tier II report of inventories for 2009 included UF_6, activated carbon pellets, magnesium fluoride, sodium chloride, sulfuric acid, grout, silica flour, gasoline, E-85 gasoline, biodiesel fuel, and diesel fuel associated with DOE activities. [UF_6 was reported even though radioactive material is not subject to EPCRA Sections 311 and 312 (52 *FR* 38344-01).]

Clean Air Act

Authority for enforcing compliance with the Clean Air Act (CAA) and subsequent amendments resides with EPA Region 4 and/or the Kentucky Division for Air Quality (KDAQ). The Paducah Site complies with federal and Commonwealth of Kentucky rules by implementing the CAA and its amendments.

Clean Air Act Compliance Status

The largest air emission sources in 2009 were the Northwest Plume Groundwater System (NWPGS) and the Northeast Plume Containment System (NEPCS). These systems are interim remedial actions (IRAs) under CERCLA that address the containment of groundwater contamination at the Paducah Site. These systems remove trichloroethene (TCE) contamination from the groundwater by air stripping. At the NWPGS, the TCE-laden groundwater passes through an air stripper to remove the TCE. The off-gas from the air stripper then passes through a carbon adsorption system to remove the TCE prior to atmospheric discharge. At the NEPCS, a cooling tower system acts as an air stripper for TCE. Concentrations of TCE in the Northeast Plume are sufficiently low that a carbon adsorption system is not required to keep emission below regulatory threshold levels.

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, as applicable, with EPA, Occupational Safety and Health Administration, and Kentucky regulatory requirements. KDAQ inspected asbestos activities on February 3, 2009. There were no noncompliances with regulatory standards identified in 2009.

Radionuclide National Emission Standards for Hazardous Air Pollutants Program

Airborne emission of radionuclides from DOE facilities are regulated under 40 *CFR* § 61, Subpart H, the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations. Potential radionuclide sources at the Paducah Site in 2009 were from C-752-A waste management activities, the NEPCS and NWPGS, C-301 DMSA Outside (OS)-12 metal reduction, and fugitive dust source emissions. The fugitive dust source emissions include piles of contaminated scrap metal, roads, and roofs. DOE utilized ambient air monitoring data to verify insignificant levels of radionuclides in off-site ambient air. The Radiation/Environmental Monitoring Section of the Kentucky Cabinet for Health Services conducted ambient air monitoring during 2009. Ambient air data were collected at 10 sites surrounding PGDP in order to measure radionuclides emitted from Paducah Site sources, including fugitive emissions. These results are discussed in further detail in Section 4.

Pollutants and Sources Subject to Regulation

Any stationary source emitting more than 10 tons/year of any hazardous air pollutant (HAP) or 25 tons/year of any combination of HAPs is considered a major source and is subject to regulation. EPA Region 4 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 HAP emissions.

Stratospheric Ozone Protection

The DOE refrigeration units contain less than 50 pounds of ozone-depleting substances; therefore, the only CAA Title VI provision that applies to the Paducah Site is the requirement to control refrigerants from leaking systems. DOE does not operate any systems that contain large amounts of refrigerants so there is no possibility of large releases of ozone depleting substances.

Clean Air Act Notices of Violation

The PGDP did not receive any CAA violations in 2009.

Kentucky/Department of Energy Agreement in Principle

The Kentucky/DOE Agreement in Principle (AIP) reflects the understanding and commitments between DOE and the Commonwealth of Kentucky regarding DOE's provision of technical and financial support to Kentucky 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 nonregulated activities, whereas, the FFA covers regulated activities. 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. Included are cooperative planning, conducting joint training exercises, and developing public information about preparedness activities.

Pollution Prevention Act

The Pollution Prevention Act of 1990 established a national policy that pollution should be prevented or reduced at the source whenever feasible. The Paducah Site supports DOE's Pollution Prevention Program mission "to reduce and, where possible, eliminate the generation and release of DOE wastes and pollutants by implementing cost-effective pollution prevention techniques, practices, and policies." The *Pollution Prevention/Waste Minimization Program Plan,* PRS/PROG/0015/R1, describes the Paducah Remediation Waste Minimization/Project Pollution Prevention (WM/PP) Program. The program includes source reduction, reuse, recycling, segregation, material substitution, and treatment as methods to reduce the quantities and toxicity of wastes and effluents. On-site recycling programs include collection of office paper, aluminum cans, plastic bottles, toner cartridges, phone books, and other waste streams for recycling. Results of the WM/PP Program are provided in the project waste minimization/pollution prevention report. Pollution prevention is discussed further in Section 3 of this ASER.

Environmental, Energy, and Economic Performance

On October 5, 2009, the President signed Executive Order (EO) 13514 *Federal Leadership in Environmental, Energy and Economic Performance*. This EO requires federal agencies to inventory, report, and reduce greenhouse gas emissions. This EO requires DOE to calculate an emissions baseline and establish targets for reduction of greenhouse gasses. The Paducah site will support DOE's goals to achieve reduced greenhouse gas emissions. Information pertaining to the achievement of these goals will be summarized in the 2010 ASER.

Other Major Environmental Issues and Actions

During 2009, an allegation was made that soil from the PGDP had been used at the Heath Elementary School between 1980 and 1981. In response to the allegation, DOE conducted a site characterization of the school grounds. The contaminants of concern, nickel, chromium, radiological constituents, and PCBs, were based on the process knowledge about the areas of PGDP where soil may have been generated during the time period in question. Results of the radiological readings and soil sampling conducted revealed no indication of PGDP process related material present on the Heath Elementary School property. This conclusion was supported by Cabinet for Health and Family Services Division of Public Health Protection and Safety Radiation Health Branch.

Regulatory Inspections

Paducah Site 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.

In 2009, the KDEP inspected the KPDES outfalls permitted under the KPDES program, the contained landfill (C-746-U), and RCRA container/tank storage facilities. In addition, KDEP (under contract of EPA Region 4) inspected TSCA compliance points. The Kentucky Department of Air Quality conducted an asbestos inspection on C-611-N and C-611-M. The inspections showed that permit conditions are being met.

3 Environmental Program Information

Abstract

Environmental monitoring, environmental restoration, materials disposition, facilities management, UF_6 cylinder management activities, D&D, and DMSA management occur at DOE facilities within PGDP. Programs that support these activities are presented in this section to inform the public.

Environmental Management System

The Environmental Management System (EMS) is designed to integrate environmental protection, environmental compliance, pollution prevention, and continual improvement into work planning and execution throughout all work areas. The Paducah site EMS is based on DOE Order 450.1A, *Environmental Protection Program*, and conforms to the five core elements of the International Organization for Standardization (ISO) EMS standard, ISO 14001. The major elements of an effective EMS include policy, planning, implementation and operation, checking, and management review. Through implementation of EMS, effective protection to workers, the surrounding communities, and the environment can be achieved while meeting operating objectives that comply with legal and other requirements. On an annual basis, EMS feedback information is analyzed to determine the status of the EMS program relative to implementation, integration, and effectiveness.

During CY 2009 PRS was under contract DE-AC30-06EW05001 to the U.S. Department of Energy (DOE) for overall program and project management of Environmental remediation activities located at the Paducah Gaseous Diffusion Plant (PGDP). During this time, PRS was responsible for compliance with all applicable laws, regulations, permit commitments, and other requirements, as defined in the contract. In the course of conducting the environmental remediation activities, PRS ensured protection of the environment. The Environmental Policy Statement emphasizes conservation and protection of environmental resources by incorporating pollution prevention and environmental protection into the daily conduct of business. PRS implemented this policy through the programs described in this document, environmental cleanup, and pollution prevention programs, and by integrating environmental protection, environmental regulatory compliance, pollution prevention, and continual improvement into the daily planning and performance of work at PGDP. The environmental policy is communicated to employees through various methods. The DOE contractor site manager reviews communicate the commitments in the policy with all of the other members of the DOE contractor management team. The policy is further communicated to all employees and to subcontractors through sitewide communication, EMS awareness training, publications, and EMS brochures.

The EMS environmental stewardship scorecard assesses agency performance in environmentally preferable purchasing; environmental management system implementation; electronics stewardship; high performance sustainable building; and environmental compliance management improvement. The 2009 scorecard for PGDP has shown improvement over 2008 in sustainable practices. Improvement also was shown in both Environmental Training and Evaluation of Compliance with Regulatory Requirements. In 2009, PGDP maintained the same scores it received in 2008 in the areas of Objectives; Targets and Programs; Operational Controls; Contracts and Concession Agreements; and Management Review.

Environmental Monitoring Program

The Environmental Monitoring Program at PGDP consists of effluent monitoring and environmental surveillance. Requirements for routine environmental monitoring programs were established to measure and monitor effluents from DOE operations and maintain surveillance on the effects of those operations on the environment and public health through measurement, monitoring, and calculation. The Environmental Monitoring Program is documented in the *Paducah Site Environmental Monitoring Plan* (PRS 2009a; PRS 2009b) in accordance with DOE Order 450.1A, *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. Since the transition on July 1, 1993, DOE's mission at the site has been focused on environmental restoration, DUF_6 cylinder management, waste management, and D&D/DMSA management. This change in mission also changed the direction and emphasis of the Environmental Monitoring Program. In November 1995, the site Environmental Monitoring Plan (EMP) was reissued to address DOE operations exclusively. The environmental monitoring plan is reviewed annually and updated at least every three years.

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 the appropriate response action is taken for the protection of human health and the environment. In May 1994, PGDP was added to EPA's NPL. Two federal laws, RCRA and CERCLA, are the primary regulatory drivers for monitoring and restoration activities at PGDP. RCRA sets the standards for managing hazardous waste and requires that permits be obtained for DOE facilities that treat, store, or dispose of hazardous waste and requires assessment and cleanup of hazardous waste releases at solid waste management units (SWMUs). CERCLA addresses uncontrolled releases of hazardous substances and requires cleanup of inactive waste sites. As a result of PGDP being placed on the NPL, DOE, EPA, and KDEP entered into an FFA in 1998. The FFA coordinates compliance with both RCRA and CERCLA requirements.

The environmental restoration program supports investigations and environmental response actions, D&D of facilities no longer in use, projects designed to demonstrate or test advancements in remedial technologies, and other projects related to action for the protection of human health and the environment.

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 TCE and ^{99}Tc. In response, DOE immediately instituted the following actions:

- Provided a temporary alternate water supply to affected residences;
- Sampled surrounding residential wells to assess the extent of contamination;
- Began extension of a 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 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 investigating 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 (SI) to identify the nature and extent of off-site contamination at the Paducah Site. Phase I of the SI, from summer 1989 to March 1991, evaluated the extent of off-site contamination through extensive groundwater monitoring and surface water sampling. Results of these activities are reported in *Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M Hill 1991). Phase II of the SI, from November 1990 to October 1991, focused on identification and characterization of on-site sources contributing to off-site contamination. Phase II 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, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (CH2M Hill 1992b). 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 1992a). This report used data collected during the SI to quantitatively assess risks to human health and to qualitatively assess risks to the environment.

As part of the residential well sampling program that began when off-site contamination was discovered, DOE established a Water Policy in 1994. This policy provides that, in the event contamination originating from the Paducah Site is detected above plant action levels, a response will be initiated by the Paducah Site. DOE modified this Water Policy in 1994 to include provisions to extend a municipal water line to the entire area of the groundwater contamination originating from the Paducah Site.

ACO activities identified two off-site groundwater contamination plumes, referred to as the Northwest and Northeast Plumes; identified several potential on-site source areas requiring additional investigation; and included the evaluation of alternatives and implementation of several interim activities. Upon signing the FFA in February 1998, the FFA parties declared that the ACO requirements were satisfied and terminated the ACO because the remaining cleanup would be continued under the authority of the FFA. A series of remedial investigations (RIs) and feasibility studies (FSs) were initiated under the FFA (e.g., Waste Area Groups 1, 3, 6, 7, 22, 23, 27, and 28), including the ongoing evaluation of all major contaminant sources impacting groundwater and surface water. In accordance with the ACO and FFA, DOE actions have focused primarily on reducing potential risks associated with off-site contamination. The following are examples of the significant actions and the dates they were completed through CY 2009:

- Imposed land use controls (fencing and posting) to restrict public access to contaminated areas in certain outfall ditches and surface water areas (1993).

- Extended municipal water lines as a permanent source of drinking water to affected residents to eliminate exposure to contaminated groundwater (1995).

- Constructed and implemented groundwater treatment systems for both the Northwest and Northeast Plumes to reduce contaminant migration (1995 and 1997, respectively).

- Rerouted surface runoff away from highly contaminated portions of the North-South Diversion Ditch (NSDD) to reduce potential migration of surface contamination (1995).
- Excavated soil with high concentrations of PCBs in on-site areas to reduce off-site migration and potential direct-contact risks to plant workers (1998).
- Removed and disposed of "drum mountain," a contaminated scrap pile potentially contributing to surface water contamination so that a potential direct-contact risk to plant workers would be eliminated and an off-site migration risk would be reduced (2000).
- Applied *in situ* treatment of TCE-contaminated soil at the cylinder drop test site using innovative technology (i.e., the Lasagna™ technology) to eliminate a potential source of groundwater contamination (2002).
- Removed petroleum-contaminated soil from SWMU 193, the former McGraw Construction Yards, now the Southside Cylinder Yards, to eliminate a potential source of groundwater contamination (2002).
- Completed installation of a sediment control basin at Outfall 001 to control the potential migration of contaminated sediment (2002).
- Completed a treatability study that demonstrated the effectiveness of the six-phase heating technology for *in situ* treatment of dense nonaqueous-phase liquid (DNAPL) at C-400 (2003).
- Completed installation of a retention basin and excavation of the on-site portions of the NSDD, which removed a source of direct-contact risk to plant workers and a potential source of surface water contamination (2004).
- Investigated potential source areas contributing to the Southwest Plume, remedial actions were evaluated (2005).
- Completed D&D of the C-603 Nitrogen Facility (2005).
- Performed an SI near the C-746-S&T Landfills and determined that TCE groundwater contamination is from SWMU 145, the Residential/Inert Landfill and Borrow Area (2006).
- Disposed of approximately 30,500 tons of scrap metal, which eliminated a potential direct-contact risk to plant workers and a source of surface water contamination (2006).
- Completed D&D of the C-402 Limehouse (2006).
- Initiated remedial design/action for volatile organic contamination in soil and groundwater at the C-400 Cleaning Building (2006).
- Completed D&D of the C-405 Incinerator (2007).
- Completed remedial action field investigation for the Burial Ground Operable Unit (2007).
- Completed D&D of the C-746-A West End Smelter (2008).
- Completed D&D of the C-342 Ammonia Disassociator Facility (2008).
- Signed an Action Memorandum, completed the Removal Action Work Plan, and initiated field work for the removal for the Soils Inactive Facilities (C-218 Firing Range and the C-410-B Holding Pond).

- Demolished two 66-year-old concrete water towers built for a World War II-era munitions plant (2009)–Figure 3.1.

Figure 3.1. C-611 Water Tower Demolition

Operable Units

The National Contingency Plan states that owners of large, complex sites with multiple source areas, such as federal facilities, may choose to divide their sites into smaller areas to characterize them and to implement response actions, rather than conducting a single sitewide comprehensive action. These discrete actions, referred to as operable units (OUs), may address a geographic portion of the site, or specific site problems, or include a series of interim actions followed by final actions. The PGDP site cleanup strategy adopts this approach and includes a series of high-priority actions, ongoing site characterization activities to support future response action decisions, and eventual D&D of the currently operating PGDP after it ceases operation, followed by a Comprehensive Sitewide Operable Unit (CSOU) evaluation. The timing and sequencing of these actions is based on a combination of factors, including risk, compliance, and technical considerations associated with PGDP operations and other criteria, as outlined in the Paducah SMP (DOE 2009a).

Groundwater

Groundwater is an example of an area that has unique technical factors that need special consideration in the sequencing and decision making process. The strategy includes the following four phases:

(1) Preventing human exposure to contaminated groundwater;

(2) Preventing or minimizing further migration of the contaminant plume;

(3) Preventing or minimizing further migration of contaminants from source materials to groundwater; and

(4) Returning groundwater to beneficial uses wherever practicable.

Phases One and Two

The first phase of the ongoing Paducah groundwater strategy focuses on preventing human exposure to contaminated groundwater by providing an alternate drinking water supply to certain area residences. The first phase is commonly referred to as the "Water Policy." The second phase of the strategy, to prevent or minimize further migration of the contaminant plumes, is being implemented through the installation of the groundwater treatment systems in both the Northwest and Northeast Plumes.

Phase Three

The third phase of the groundwater strategy is focused on the prevention or minimization of contaminant migration from source areas. As part of this phase, installation of the electrical resistance heating remedial action for the C-400 area—the largest known DNAPL source of off-site contamination was initiated in 2009. A primary objective of this project is to contribute to the protection of off-site residences by addressing sources of groundwater contamination. The third phase also includes investigation of the BGOU, which was completed in 2007, and the Sitewide Soils OU to determine the presence of any additional groundwater contaminant sources and their contribution to the off-site plumes, if any. The third phase also will include a Groundwater OU (GWOU) project focused exclusively on the dissolved-phase plumes, including further assessment of the Northwest and Northeast Dissolved-Phase Plumes as well as the Southwest Dissolved-Phase Plume.

Phase Four

The fourth phase of the groundwater strategy is the evaluation of the technical practicability of returning groundwater to its expected beneficial use within a reasonable time frame. The evaluation will be conducted as part of the CSOU. Several technical factors must be considered in making a final decision for the groundwater, including the effectiveness of all source actions taken prior to the final one, the presence of any as yet unknown DNAPL source areas [including areas beneath the gaseous diffusion plant (GDP)] that might be contributing to groundwater contamination and require response action; and any effects that ceasing plant operations may have on groundwater flow. Each of these technical considerations is essential to effective remediation of the contaminants associated with the plumes. Some of these technical factors or data gaps cannot be completed until the plant ceases operations.

D&D

The scope of the D&D OU includes 20 currently inactive DOE facilities and those SWMUs and areas of concern associated with previous GDP operations and the currently operating GDP. Seventeen inactive facilities have been completed and one inactive facility associated with the Soils OU (holding pond) is in process, along with the interior components of the C-410/420 Complex. D&D activities recently began for the C-340 Metals Plant. The units associated with current GDP operations will be addressed during D&D of the GDP.

Final CSOU

The final CSOU evaluation will occur following completion of D&D of the GDP after plant shutdown. As part of the final CSOU evaluation, the land-use assumptions will be reassessed and modified, if necessary, to ensure consistency with the reasonably foreseeable land use, including any reuse initiatives that might be under consideration at that time. The final CSOU will include a sitewide baseline human health and ecological risk assessment to evaluate residual risks remaining and to identify any additional actions necessary to ensure long-term protectiveness.

CY 2009 Response Activities

Significant accomplishments for the Environmental Restoration Program conducted in CY 2009 include, but were not limited to, the following:

- Completed remedial design and development of Remedial Action Work Plan and began fieldwork for C-400 Interim Remedial Action for volatile organic contamination in soil and groundwater at the C-400 Cleaning Building, the site's largest source of groundwater contamination.
- Developed an FS for the Southwest Groundwater Plume Volatile Organic Compound (VOC) Sources.
- Continued operation of the Northwest and Northeast Plume groundwater treatment systems.
- Signed an Action Memorandum, completed the Removal Action Work Plan, and initiated field work for the for the Surface Water OU on-site hot spot removal action.
- Completed removal of contaminated soils at the C-218 Firing Range.
- Completed sampling and issued reports for the soil and rubble near Bayou Creek and other areas surrounding PGDP and in Ballard County, Kentucky.
- Submitted the RI report for the BGOU field investigation of approximately 60 acres of old burial grounds and began drafting remedial decision documents.
- Initiated installation of Phase I system components for remedial action for TCE contamination in soil and groundwater at the C-400 Building utilizing electrical resistance heating technology (2009).

C-400 Interim Removal Action for Volatile Organic Compound Contamination in Groundwater

In 2005, a Record of Decision (ROD) was approved by DOE and submitted to the regulators for selecting the IRA for the GWOU VOCs source zone, comprised primarily of TCE, at the C-400 Cleaning Building at PGDP. The ROD includes discussion of the contribution that this IRA will make toward the final decision for the GWOU at PGDP.

The IRA was developed to accomplish the following:

- Prevent potential exposure to contaminated groundwater to on-site industrial workers through institutional controls (e.g., excavation/penetration permit program); and
- Initiate remedial design for the C-400 groundwater action fieldwork. Reduce contamination comprised of TCE and other VOCs found in UCRS soil in the C-400 Cleaning Building area to minimize the migration of these contaminants to RGA groundwater and to off-site points of exposure.

The major components of the remedy would include the following:

- Reduce the concentration of TCE and other VOCs in the soils in the C-400 Cleaning Building area through removal and treatment using electrical resistance heating in both the UCRS and RGA;
- Collect post-action sampling results;
- Conduct a Remedial Design Support Investigation to further determine areal and vertical extent of TCE and other VOC contamination in the C-400 Cleaning Building area to ensure optimum placement of the remediation system; and
- Implement land use controls at the C-400 Cleaning Building area.

In 2009, the installation for Phase I of the remedial action was initiated and preparations for system startup continued through early 2010 (Figure 3.2).

Figure 3.2. Treatment System for TCE-Contaminated Soil and Groundwater

Southwest Plume Site Investigation

The *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2180&D2 (DOE 2006a), documents a 2004 investigation of the on-site Southwest Plume area. The SI was conducted in accordance with the approved *Site Investigation Work Plan for the Southwest Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2094&D2 (DOE 2004). The objectives of the SI were to collect sufficient data to do the following:

- Determine which units are sources of contamination to the Southwest Groundwater Plume;
- Determine which units are not sources of contamination to the Southwest Groundwater Plume;
- Fill data gaps for risk assessment of the identified source areas; and
- Reduce uncertainties and increase the understanding of the Southwest Groundwater Plume and potential sources so that appropriate response actions can be identified, as necessary.

The investigation evaluated the following four potential source areas of contamination to the Southwest Groundwater Plume and profiled the level and distribution of VOCs and ^{99}Tc in the plume along the western plant boundary.

(1) C-747-C Oil Landfarm (SWMU 1)
(2) C-720 Building, specifically areas near the northeast and southeast corners of the building
(3) Storm sewer between the south side of the C-400 Building and Outfall 008 (a part of SWMU 102)
(4) C-747 Contaminated Burial Yard (SWMU 4), addressed in BGOU RI/FS

Very little investigation previously has focused on the storm sewer as a potential source of groundwater contamination. Three of the four potential source areas and the dissolved-phase plume have been addressed in earlier investigations.

As a result of reviews conducted by the EPA regarding the Southwest Plume SI Report (DOE 2004), DOE entered into dispute resolutions with the EPA during 2007. As a result of the negotiations, it was agreed that a focused FS would be developed. The FS was developed in 2009 and submitted to EPA and the Commonwealth of Kentucky for review and approval in 2009.

Northwest Plume Groundwater System

The IRA for the Northwest Plume is documented in a ROD signed by DOE and EPA in July 1993. KDEP concurred with the ROD. The results of the IRA led to the construction of the NWPGS. The NWPGS consists of two extraction well fields (each containing two extraction wells) transfer pipelines, and a fully enclosed treatment system. The NWPGS began operation August 28, 1995. The NWPGS, an interim action, is designed to reduce off-site migration of the high concentration portions of TCE and ^{99}Tc in the Northwest Plume. TCE is removed by an air stripping process. The TCE is volatilized in a low-profile air stripper by introducing a large volume of air into the contaminated groundwater. Activated carbon filtration beds then are used to remove the TCE from the off-gas generated by the air stripper before the air is discharged to the atmosphere. ^{99}Tc is removed from the groundwater by an ion exchange process.

The NWPGS has extracted and treated over 1.4 billion gal of contaminated groundwater from startup in 1995 through the end of 2009. The NWPGS consistently has met the treatment goals documented in the ROD of 5 ppb TCE and 900 pCi/L of ^{99}Tc. The treated groundwater is released through KPDES-permitted Outfall 001. 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 EPA in June 1995. The KDEP accepted the ROD. The NEPCS, an interim action, is designed to reduce off-site migration of the high concentration portions of TCE in the Northeast Plume. The NEPCS consists of two extraction wells, an equalization tank, a transfer pump, a transfer pipeline, and instrumentation and controls. Characterization and construction activities were completed in December 1996. System startup and operational testing were conducted, and full operation began in February 1997.

System operation includes pumping groundwater contaminated with TCE from two extraction wells to the equalization tank. A transfer pump is used to pump the contaminated water from the equalization tank through a transfer pipeline (approximately 6,000 linear ft) to the top of the C-637-2A or C-637-2B Cooling Tower. C-637-2A is the primary destination; however, if C-637-2A is off-line, flow is transferred to the C-637-2B tower. The cooling tower acts as an air stripper and removes the TCE from the groundwater as it moves through the tower.

Through 2009, over 1 billion gal of contaminated groundwater have been extracted and treated by the NEPCS.

Surface Water Operable Unit (On-Site)

The results of the *Site Investigation and Risk Assessment of the Surface Water Operable Unit (On-site)*, DOE/OR/07-2137&D2/R2 (DOE 2007a), the Baseline Human Health Risk Assessment (BHHRA), and the Screening Ecological Risk Assessment (SERA) for the Surface Water OU (On-Site) have been summarized in the *Surface Water Operable Unit (On-Site) Site Investigation and Baseline Risk Assessment Report,* DOE/LX/07-0001&D2/R1 (DOE 2008).

Based upon the results of the SI/baseline risk assessment (BRA), hot spots (sediment located within the NSDD and outfall ditches defined in the SI/BRA as areas where contamination exceeds indicator levels in the SI indicating that unacceptable risk to human health and/or the environment may exist) were identified in the areas investigated. In response to the SI/BRA findings, a non-time-critical removal notification, *Removal Notification for the Surface Water Operable Unit (On-Site),* DOE/LX/07-0011&D1 (DOE 2007b), was issued and approved by the regulators in CY 2007. The project prepared and submitted and engineering evaluation/cost analysis (EE/CA) in CY 2008. During CY 2008, the EE/CA obtained regulatory approval. The EE/CA provided the basis for the development of the Action Memorandum that was approved in CY 2009. A *Removal Action Work Plan for Contaminated Sediment Associated with the Surface Water Operable Unit (On-Site),* DOE/LX/07-0221D2/R1, (DOE 2009b) was approved and field work was initiated in late 2009.

The scope of the Surface Water OU (On-Site) includes the following:

- NSDD Sections 3, 4, and 5;
- PGDP Outfalls 001 (those portions not addressed by the scrap metal basin), 002, 008, 010, 011, 012 (those portions down gradient of the storm sewer discharge point), and 015, and associated internal ditches and areas (including SWMU 92 and SWMU 97); and
- PGDP storm water sewer systems associated with C-333-A, C-337-A, C-340, C-535, and C-537.

Soil and Rubble Areas Investigation

In November 2006, several soil and rubble areas were found outside the fence on DOE property. To facilitate the site evaluation process, the soil and rubble areas were divided into four separate groups and prioritized for the purpose of undergoing sampling and analysis. The four separate groups are as follows: Little Bayou Creek Soil Pile I (east side of the plant); Little Bayou Creek Pile including AOCs 541 and 492 (east and north sides of the plant); Bayou Creek Pile (west side of the plant); and rubble areas (most on west side of the plant). During 2007, Soil Pile I was characterized as required in the sampling and analysis plan and associated Addendum 1-A. Addenda 2 and 1B soil areas were characterized in 2008 and the Site Evaluation Reports were drafted for the areas. Rubble area sampling and removal as a maintenance action was completed in CY 2009. Reports have been issued for all areas sampled and these reports are undergoing regulatory review. Once these reports are completed, plans will be developed to implement any necessary removal actions.

To support ongoing soil activities, a Scoping Survey Plan was implemented in 2009. The Scoping Survey Plan entailed a walkover and flyover of DOE and WKWMA areas outside of the limited access area to determine if any additional anomalies are present and, if so, characterize them to determine the potential nature and extent of contamination for future actions, if required. Results are being reviewed and future activities are planned as part of a Sitewide Evaluation Work Plan being developed to ensure that any additional areas of contamination are identified and addressed as part of the remedial action program.

Burial Grounds Operable Unit Remedial Investigation/Feasibility Study

The *Work Plan for the Burial Grounds Operable Unit Remedial Investigation/Feasibility Study at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-2179&D2/R1 (DOE 2006b), was issued to the regulators on August 28, 2006, and was revised in November 2006. The goals for the BGOU RI/FS are consistent with those established in the FFA and the Paducah SMP (DOE 2009a) negotiated among DOE, EPA, and the KDEP. The goals of this RI/FS are as follows.

Goal 1: Characterize Nature of Source Zone—Characterize the nature of contaminant source materials by using existing data and, if required, by collecting additional data.

Goal 2: Define Extent of Source Zone and Contamination in Soil and Other Secondary Sources at All Units—Define the nature, extent (vertical and lateral), and magnitude of contamination in soils, sediments, surface water, and groundwater by using existing data and, if required, by collecting additional data; determine the presence, general location (if practicable), and magnitude of any DNAPL zones as defined in the Paducah SMP (DOE 2009a).

Goal 3: Determine Surface and Subsurface Transport Mechanisms and Pathways—Gather existing quality data and, if necessary, collect additional adequate quality data to analyze contaminant transport mechanisms, evaluate risk, and support an FS.

Goal 4: Support Evaluation of Remedial Technologies—Determine if the existing data are sufficient to evaluate alternatives that will reduce risk to human health and the environment and/or control the migration of contaminants off-site.

The RI was performed from January through May 2007. The focus of the BGOU RI/FS Work Plan was to collect field and analytical data necessary to determine the nature and extent of any soil and groundwater contamination originating from, and immediately under, the burial cells; support the completion of a BHHRA and SERA; and evaluate appropriate remedial alternatives (if necessary) at each of the SWMUs. The RI addresses Goals 1–3. The *Remedial Investigation Report for the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-0030&D1/R1, (DOE 2009c) was issued to the regulators on April 8, 2009, and a revised report was issued on October 6, 2009 (DOE 2009d). The FS was continued in 2009 to further address Goal 3 and complete Goal 4.

Materials Disposition Program

The Paducah Site Materials Disposition 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. Waste managed under the program is divided into the following eight categories.

(1) *Hazardous waste*—Waste that contains one or more of the wastes listed as hazardous under RCRA or that exhibits one or more of the four RCRA hazardous characteristics: (1) ignitability, (2) corrosivity, (3) reactivity, and (4) toxicity.

(2) *Mixed waste*—Waste containing both a hazardous component regulated under RCRA and a radioactive component regulated under the Atomic Energy Act.

(3) *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.

(4) *Low-level radioactive waste (LLW)*—Radioactive waste not classified as high-level or transuranic.

(5) *PCB-containing and PCB-contaminated waste*—Waste containing or contaminated with PCBs.

(6) *Asbestos waste*—Asbestos-containing materials from renovation and demolition activities.

(7) *Solid waste*—Solid sanitary/industrial waste basically is refuse or industrial/construction debris and is disposed of in landfills.

(8) *PCB radioactive waste*—PCB waste or PCB items mixed with radioactive materials.

In addition to compliance with current regulations, DOE supplemental policies are enacted for management of radioactive, hazardous, PCB, PCB/radioactive, and mixed wastes. These policies include reducing the amount of wastes generated; characterizing and certifying waste before it is stored, processed, treated, or disposed of; and pursuing volume reduction and use of on-site storage, if safe and cost-effective, until a final disposal option is identified. In 2009, activities were focused on completing the disposal of legacy waste. Over the project life cycle, more than 1.1 million ft^3 of waste, including DMSA material, has been dispositioned.

Waste Minimization/Pollution Prevention

The Waste Minimization/Pollution Prevention Program (WM/PP) at the Paducah Site provides guidance and objectives for minimizing waste generation. The program is set up to comply with RCRA and the Pollution Prevention Act, as well as applicable Commonwealth of Kentucky and EPA rules, DOE Orders, Executive Orders, and the STP. All PGDP projects are evaluated for WM/PP opportunities.

The program strives to minimize waste using the following strategies: source reduction, segregation, reuse of materials, recycling, and procurement of recycled-content products.

The program has the following goals and objectives:

- Reducing the quantity of wastes generated at their sources;
- Reusing or recycling materials;
- Identifying waste reduction opportunities;
- Integrating WM/PP technologies into ongoing projects;
- Coordinating recycling programs; and
- Tracking and reporting results.

Accomplishments of the WM/PP Program in 2009 include the following:

(1) Segregated all wastes found and/or generated to reduce the amount of LLW, mixed, hazardous, and PCB-contaminated wastes.

(2) Adhered to procedures that require employees to segregate individual items of personal protective equipment (PPE) according to the type of contaminants on them, and to place contaminated PPE into the waste containers that were the original contamination source of the PPE.

(3) Continued solid waste prevention practices which included: spent fuel filter recycling, clean scrap metal recycling, enhanced battery and electronic recycling, reuse of railroad ties, reuse of concrete test cores, reuse of waste soil as landfill cover after determination that the soils is clean by additional sampling, reuse of waste soil as a radiation shielding berm, and reuse of railroad tracks.

(4) Continued using collection areas for the recycling of certain items such as various types of batteries, fuses, and circuit boards.

(5) Recycled scrap metal, paper, tires, batteries, used oil, cardboard, toner cartridges, aluminum cans, and light bulbs.

(6) Utilized sustainable practices as part of purchasing activities.

(7) Waste minimization and pollution prevention efforts during CY 2009 recycled 7,273,623 lbs of materials. Materials recycled included paper, cardboard, batteries, various metals, tires, toner cartridges, wood pallets, oils, antifreeze, and fluorescent bulbs.

The Office of the Federal Environmental Executive and EPA recognized the DOE Paducah Site as a silver-level award winner in the 2009 Federal Electronics Challenge. The award recognized the achievements in electronic stewardship actions undertaken that helped the federal government improve its sustainable practices when purchasing, managing, and disposing of their electronic assets.

Depleted Uranium Hexafluoride Cylinder Program

A product of the UE process, DUF_6 is a solid at ambient temperatures and is stored in large metal cylinders. At the end of 2009, the Paducah Site managed an inventory of approximately 38,000 cylinders containing approximately 454,000 metric tons of UF_6 (most containing DUF_6) stored in outdoor facilities, commonly referred to as cylinder storage yards. The inventory varies from time to time as a result of DOE agreements to receive or market DUF_6.

Stored as a crystalline solid at less than atmospheric pressure, when DUF_6 is exposed to moisture in the atmosphere, hydrogen fluoride and uranyl fluoride form. The uranium by-products form a hard crystalline solid that acts as a self-sealant within the storage cylinder. The acute hazard potential of DUF_6 primarily is chemical toxicity from any released hydrogen fluoride.

The mission of the DUF_6 Cylinder Program is to safely store the DOE-owned DUF_6 inventory until its ultimate disposition. DOE has an active cylinder management program that includes cylinder and cylinder yard maintenance, routine inspections, and other programmatic activities such as cylinder corrosion studies. The program maintains a cylinder inventory database that serves as a systematic repository for all cylinder inspection data.

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* (DOE 1999). In 2002, DOE selected UDS to design, build, and operate facilities at Paducah, Kentucky, and Portsmouth, Ohio. The facilities would convert the inventory of DUF_6 to triuranium octoxide, a more stable form of uranium that is suitable for disposal or reuse, and hydrofluoric acid that will be sold for commercial use.

Consistent with Public Law 107-206, construction began in July 2004 and continued through 2008. During 2008, all support structures/facilities were constructed. The majority of major operational equipment was delivered and placed. Installation of piping, electrical, and instrumentation has begun as well as bringing the site up to final grade with either rock and/or asphalt/concrete. Physical construction of the facility was completed on December 19, 2008 (Figure 3.3). Following systems testing and thorough readiness reviews, operation is scheduled to being in 2010.

Figure 3.3. DUF_6 Facility

Decontamination and Decommissioning

D&D is conducted for inactive facilities and other structures contaminated with radiological and hazardous material. Facilities are accepted for D&D when they no longer are required to fulfill a site mission. Twenty facilities were targeted for D&D by DOE. By the end of CY 2009, demolition had been completed for 17 of those facilities. The remaining facilities are C-746-A East End Smelter, C-410 Feed

Plant, and C-340 Metal Reduction Plant. The C-340 Metal Reduction Plant complex converted UF_6 to uranium metal and hydrogen fluoride, and the C-410 UF_6 Feed Plant complex converted uranium trioxide to UF_6. The C-746-A East End Smelter was used to recover metal from various pieces of equipment. Contaminants at these facilities include depleted uranium, natural uranium, transuranic radionuclides, uranium tetrafluoride, PCBs, asbestos, and lead paint.

Removal of the C-410 Complex infrastructure is being completed as a CERCLA non-time-critical removal action. In 2009, the C-410 Action Memorandum (AM) was expanded via an addendum to include building demolition as the selected response action. DOE received EPA (November 23, 2009) and the Commonwealth of Kentucky (November 16, 2009) approval of the AM Addendum. CERCLA documentation for D&D of the C-340 Complex and C-746-A East End Smelter is planned for 2010.

ARRA funds provided to the Paducah Site in 2009 are being used to remove and dispose of large process equipment and demolish surplus chemical processing facilities, shrinking the area of contamination. ARRA funding for Paducah totaled approximately $78.8 million to accelerate the current D&D Program for three facilities (Figure 3.4). The three facilities are as follows:

- C-746-A East End Smelter demolition and debris removal
- C-340-D and C-340-E demolition to slab and prepare C-340-A, B, and C for demolition
- C-410 Feed Plant demolition to slab

Figure 3.4. Facilities Utilizing ARRA Funding

The following are significant D&D accomplishments in 2009:

- Developed plans and regulatory documents for demolition of the C-746-A East End Smelter and C-340 Metal Reduction Plant complex.

- Modified CERCLA documents as necessary to continue with demolition activities at the C-410 UF_6 Feed Plant complex.

- Asbestos-containing material (ACM) removal was completed for all 65 zones in C-410 UF_6 Feed Plant complex.

- A total of 37,966 ft^3 of waste, including radiological and mixed (radiological and RCRA hazardous or TSCA), was shipped from the C-410 UF_6 Feed Plant complex for treatment and disposal at the Energy*Solutions* Clive Operations Facility.

- Completed demolition of the C-611 Water Towers.

- Approximately 12 tons of D&D waste was sent to the C-746-U Landfill in 2009.

DOE Material Storage Areas

DMSAs are areas at PGDP containing uninventoried DOE material and equipment that require characterization. They are undergoing a characterization process consistent with requirements associated with nuclear criticality safety, RCRA, TSCA, and solid waste concerns. The 160 DMSAs originally were included with PGDP facilities leased to USEC. To facilitate Nuclear Regulatory Commission certification of PGDP, DMSAs were returned to DOE from USEC December 31, 1996. The DMSAs are located either in nonleased areas inside buildings leased to USEC or in nonleased outdoor areas.

The Kentucky Environmental and Public Protection Cabinet (now the Kentucky Energy and Environment Cabinet) filed an administrative complaint in October 2001 regarding the enforcement of NOVs that alleged violations of Kentucky’s hazardous waste management program. Most of these NOVs alleged the failure to characterize materials in the DMSAs at PGDP or the unpermitted storage of hazardous waste in the DMSAs.

In October 2003, an AO between DOE and the Commonwealth of Kentucky was signed that resolved the administrative complaint. The AO established regulatory deadlines for characterization of hazardous waste from the DMSAs and also established requirements relating to RCRA closure for the DMSAs that are found to contain hazardous waste. All DMSA material has been disposed of/reassigned prior to the end of CY 2009. The reassigned material includes characterized equipment that has been transferred to future D&D projects.

Requirements to complete Priority A and Priority B DMSAs were met in 2004 and 2006, respectively. Requirements for priority C DMSAs were completed in CY 2009. At project completion in 2009, all DMSAs (160) totaling over 830,000 ft^3 of material were characterized. Figure 3.5 shows the final shipment of DMSA material.

Figure 3.5. Final DMSA Material Leaving PGDP

Public Awareness Program

A comprehensive Community Relations and Public Participation Program exists for DOE activities at the Paducah Site. The purpose of the program is to provide the public with opportunities to become involved in decisions affecting environmental issues at the site.

Community/Educational Outreach

DOE and PRS Public Affairs supported several educational and community outreach activities during 2009. DOE managers spoke with civic groups, business leaders, and residents at prearranged events and at the regular board and task force meetings of the PGDP Citizens Advisory Board (CAB).

In March 2009, DOE held a public information session requesting input for the evaluation of disposition options for waste generated by facility D&D and future environmental cleanup actions at the Paducah Site. This evaluation includes on-site and off-site disposal options. Additional public meetings are planned as the evaluation process continues.

Citizens Advisory Board

The PGDP CAB, a site-specific advisory board chartered by DOE under the Federal Advisory Committees Act, completed its thirteenth full year of operation in September 2009. During the year, the CAB held five regular board meetings, five committee meetings, and one retreat. The CAB includes five committees, which meet as necessary.

The committees review issues for the following areas:

- Burial Grounds
- Community Outreach
- Future End Use
- Groundwater, Surface Water, and Soils
- Waste and D&D

All meetings are open to the public and all regular board meetings are publicly advertised. In addition to its voting members, the CAB also has liaison members representing DOE, Kentucky, and EPA. In 2009, the CAB had 15 voting members, 4 liaison members, a deputy-designated federal official, and a federal coordinator.

The CAB is composed of up to 18 members, chosen to reflect the diversity of gender, race, occupation, views, and interests of persons living near the PGDP. The CAB is committed to reflecting the concerns of the communities impacted by environmental management of the plant site. It meets monthly, except in December, to focus on early citizen participation in environmental cleanup priorities and related issues at the DOE facility. Additional information concerning the CAB may be obtained at www.pgdpcab.org.

End State Vision Document

The End State Vision Process for PGDP was initiated in 2004. The End State Vision Document was developed and issued in August 2005 as a planning tool for the site's future use. This process identifies the condition of the property after cleanup that would be protective of human health and the environment, while taking into account the future use of the property (e.g., industrial, recreational, or residential) and any potential contaminants and hazards. The process also identifies any variances between the currently planned end state and the potential alternative end state.

The *Update to the End State Vision for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE/LX/07-0013&D1) issued in 2008 contained the following significant changes:

- Updated information for the Surface Water OU, based on the recently completed Surface Water OU (On-Site) SI;
- Updated information for the GWOU, based on the recently initiated implementation of ROD remedy;
- Added information regarding the identification of soil and rubble areas that may contain contaminated soils or materials both on and off DOE property;
- Modified title to be consistent with the Portsmouth DOE facility document;
- Added information regarding PGDP cleanup strategy consistent with the Site Management Plan; and
- SWMU 3 moved from Hazard Area 3 (BGOU Group 1) to Hazard Area 1 GWOU to be consistent with the GWOU strategy and some recently collected information regarding possible contaminant migration from this unit.

Environmental Information Center

The public has access to Administrative Records and programmatic documents at the DOE Environmental Information Center (EIC) in the Barkley Centre, 115 Memorial Drive, Paducah, Kentucky. The EIC is open Monday through Friday from 8 a.m. to 12 p.m. and by appointment. The EIC's phone number is (270) 554-6979.

Documents for public comment also 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 through Saturday from 9 a.m. to 6 p.m., and Sunday from 1 p.m. to 6 p.m.

The EIC and other public Web pages related to DOE work at the PGDP can be accessed at www.pppo.energy.gov/pad_eic.html.

4 Radiological Effluent Monitoring

Abstract

Releases to the atmosphere from the NWPGS, NEPCS, C-301 DMSA OS-12 Waste Removal Project, and the C-752-A waste management activities were estimated for 2009. The calculated emissions for each activity were less than the 40 CFR § 61, Subpart H, limit of 0.1 mrem dose to the maximally exposed individual. Dose to the public from airborne radionuclides is discussed in Section 6.

Analyses of samples of liquid effluents from PGDP indicate that detectable levels of uranium and ^{99}Tc are at levels that are protective of human health.

Introduction

Some materials like uranium, which consists of several types of radionuclides, are radioactive and give off radiation when the nucleus breaks down or disintegrates. The three kinds of radiation generated by radioactive materials or sources are alpha particles, beta particles, and gamma-rays. When ionizing radiation interacts with the human body, it gives its energy to the body tissues. The amount of energy absorbed per unit weight of the organ or tissue is called absorbed dose. Many radiation sources are naturally occurring and are considered terrestrial sources (i.e., sun, earth). The body absorbs the radiation from these terrestrial sources, as well as sources that are not naturally occurring. Radioactivity can be measured in differing units (i.e., becquerel, curies). PGDP effluents are monitored for these radionuclides that are known to be present, either now or in the past.

The monitoring program for radioactivity in liquid and airborne effluents is described fully in Paducah Site EMPs. The Paducah Site EMP is reviewed and updated each October; therefore, during 2009, the required monitoring was conducted under two separate EMPs. Data collected January through September 2009 followed the 2009 EMP, and data collected from October through December 2009 followed the 2010 EMP.

Airborne Effluents

In accordance with DOE Order 450.1A, effluent monitoring is to be conducted to meet *General Environmental Protection Program Standards.* DOE Order 5400.5, *Radiation Protection of the Public and the Environment,* sets dose standards for members of the public at 10 mrem per year from airborne releases and at 100 mrem per year through all exposure pathways resulting from routine DOE operations.

Radiological airborne releases from DOE facilities also are regulated under 40 *CFR* § 61, Subpart H, which governs radionuclide emissions, other than radon. Emissions of radionuclides to ambient air from DOE facilities shall not exceed an effective dose equivalent of 10 mrem/year to any member of the public. The dose equivalent is based on a potential exposure to a hypothetical resident who has the greatest chance of being affected by a release of airborne contaminants also known as the maximally exposed individual.

DOE had the sources described here of airborne radionuclides in 2009. DOE also had fugitive air sources that were measured by air monitoring stations around the site that are discussed in Section 5. A complete summary of this emissions data can be found in the *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2009*, PRS-REG-0010, dated June 2010.

The total estimated dose from all DOE emissions in 2009 was 0.00015 mrem to the maximally exposed individual. Dose calculations for these atmospheric releases are discussed in Section 6 of the ASER. All separate emission values, as well as the summed values, are below the regulated emission criteria of 10 mrem/year.

Northwest Plume Groundwater System

The CERCLA IRA ROD, signed July 22, 1993, established the NWPGS. Although administrative requirements (e.g., permits) of environmental regulations do not apply to projects conducted under CERCLA, DOE has continued to provide pertinent information about emissions to the regulators. The Operations and Maintenance Plan describes sampling and methodologies to be used at the NWPGS. The air emissions methodology is to estimate air emissions based on influent water sample results. The analysis of the air stripper influent water provides a more accurate measurement of airborne discharges than actual stack measurements due to the low, practically immeasurable, radionuclide airborne effluents associated with the facility.

On August 28, 1995, DOE began operation of the NWPGS. The facility is located just outside the northwest corner of the PGDP security area. The facility consists of an air stripper to remove volatile organics and an ion exchange unit for the removal of ^{99}Tc from water. The air stripper is located upstream of the ion exchange unit. The ^{99}Tc concentration in the influent and effluent water of the air stripper and the quantity of the water passing through the air stripper were used to calculate total potential ^{99}Tc emissions from the facility in 2009. The emissions were used to calculate dose rates associated with this operation. 2009 releases to the atmosphere from the NWPGS were estimated to be 8.20E-05 curies (Ci) of ^{99}Tc.

Northeast Plume Containment System

The NEPCS is a CERCLA interim action to remediate contaminated groundwater. Although administrative requirements (e.g., permits) of environmental regulations do not apply to projects conducted under CERCLA, DOE has continued to provide pertinent information about emissions to the regulators. In 2009, ^{99}Tc was detected in small amounts in the groundwater that was extracted.

The wells and pumping facility are located northeast of the PGDP security area. The water is pumped to the C-637-A Cooling Tower where the contaminants evaporate from the extracted groundwater. The ^{99}Tc concentration and the quantity of the water pumped to the cooling tower were used to calculate total potential ^{99}Tc emissions from the facility in 2009. The estimated emissions from the NEPCS were estimated to be 4.44E-06 Ci of ^{99}Tc.

C-301 DMSA Outside-12

During 2009, C-301 DMSA OS-12 continued metal size reduction and packaging for off-site disposal. Figure 4.1 shows metal size reduction being performed at C-301 DMSA OS-12. Fugitive airborne radionuclide emissions may have resulted from dust created by these activities. The estimated emissions from DMSA OS-12 were 1.44E-07 Ci.

Figure 4.1. Metal Size Reduction at C-301 DMSA OS-12

C-752-A Waste Management Activities

During 2009, waste containing uranium precipitate was repackaged. The particulate waste was repackaged in a ventilated enclosure within C-752-A. The ventilation for the enclosure passes through high-efficiency particulate air filters and then is exhausted through two stacks. The estimated emissions from these activities were 3.58E-05 Ci.

Liquid Effluents

The CWA for the Paducah Site is administered by KDOW through the KPDES Wastewater Discharge Permitting Program. The sitewide KPDES permit (KY0004049) became effective November 1, 2006. This permit was challenged by citizen groups, DOE, USEC, and UDS; consequently, the conditions of the previous permit remained in effect, for most of the 2009 reporting period, except for the monitoring requirements. In addition to nonradiological parameters on the KPDES permit, specific radionuclide analyses, in addition to gross alpha and beta activity analyses, are conducted on liquid effluent samples. Grab samples and composite samples collected at weekly or monthly monitoring frequencies are used to measure discharges. Figure 4.2 illustrates KPDES outfalls and landfill surface water monitoring locations.

DOE Orders 450.1A and 5400.5 establish effluent monitoring requirements to provide confidence that radiation exposure limits of 100 mrem per year are not exceeded. DOE Order 5400.5 sets guidelines for allowable concentrations of radionuclides in various effluents to protect public health and requires radiological monitoring. This protection is achieved at the Paducah Site by meeting derived concentration guidelines (DCGs), which are the concentrations of given radionuclides that would result in an effective dose equivalent of 100 mrem per year. The DCGs are based on the assumption that a member of the public has continuous, direct access to the liquid effluents. In reality, exposure is not continuous;

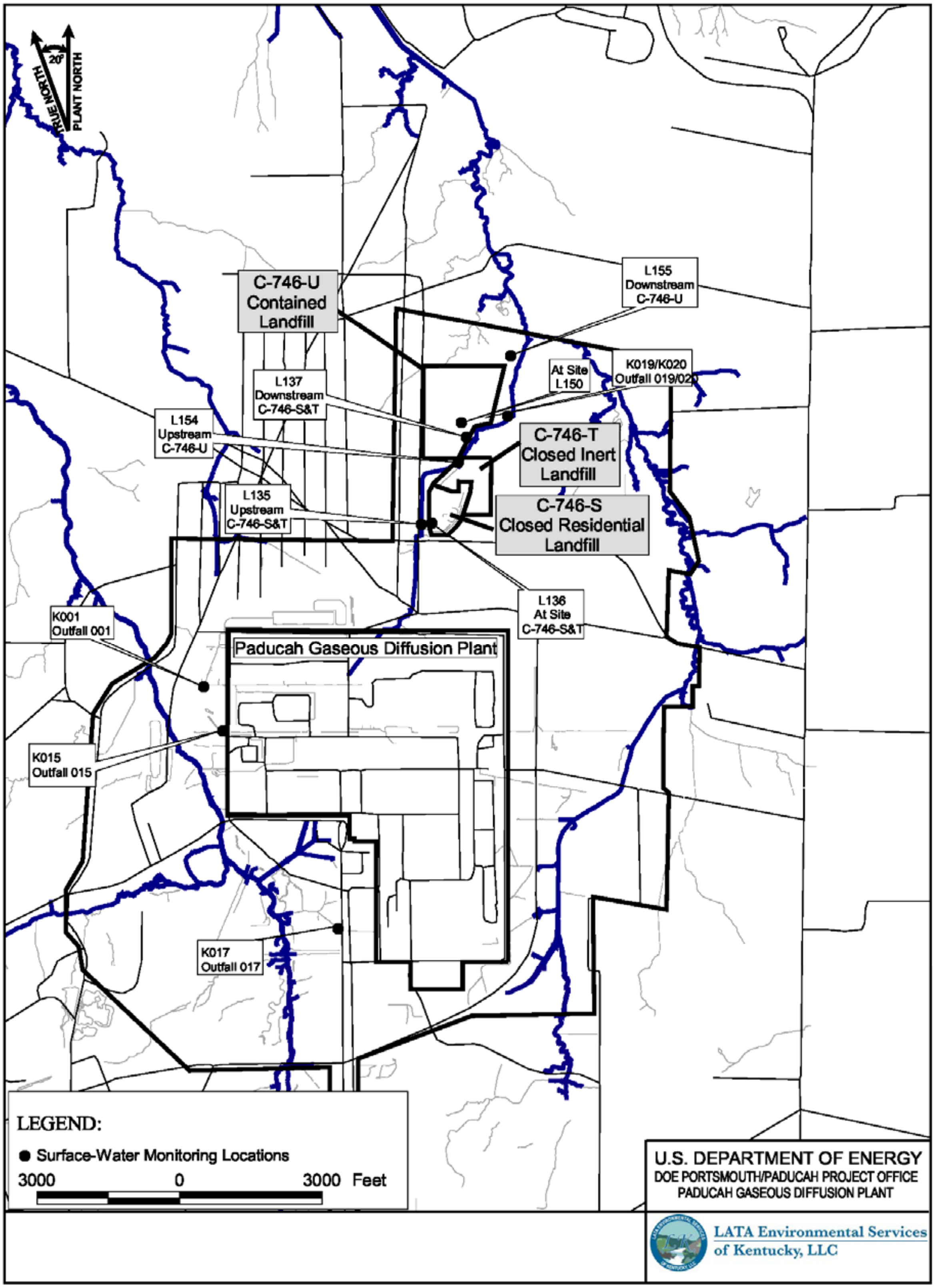

Figure 4.2. KPDES Outfalls and Landfill Surface Water Monitoring Locations

therefore, the allowable concentrations for the DCGs are very conservative. Further information on DCGs is provided in Appendix B.

For monitoring purposes, the Paducah Site uses estimates of DCG levels and outfall flow characteristics (rainfall dependent) to determine sampling frequencies. Neither continuous monitoring nor continuous sampling is required by DOE Order 5400.5. Sampling for radiological priority pollutants was not required by the KPDES permit; however, the analyses will be performed twice prior to the KPDES renewal application in May 2011.

Other radiological effluent monitoring is required by KDWM landfill permits SW07300014, SW07300015, and SW07300045 for the C-746-S, C-746-T, and C-746-U Landfills, respectively. Surface runoff is analyzed to determine if landfill constituents are being discharged into nearby receiving streams.

Outfall 001 is a continuous flow outfall that receives discharges from a variety of permitted units, including the following:

(1) USEC's C-616 Liquid Pollution Abatement Facility (LPAF), a once-through cooling water system, 0.8 million gal per day (MGD);

(2) DOE's NWPGS, 0.3 MGD;

(3) DOE's waste management activities including routinely generated C-404 treated leachate, C-733 and C-612-A sump water, and other waste management activities resulted in a cumulative discharge of approximately 40,000 gal; and

(4) DOE's discharge operations at the Northwest Stormwater Collection Basin (also referred to as the C-613 Sedimentation Basin). Figure 4.3 shows the C-613 Sedimentation Basin.

Figure 4.3. C-613 Sedimentation Basin

DOE's NEPCS is treated through the C-637 Cooling Tower; the water from this is transferred to C-616 LPAF for air stripping Next, the water is transferred by an underground pipeline to the C-616-F Full Flow Lagoon, and ultimately discharged into Outfall 001. In addition, surface-water runoff is collected in the C-613 Sedimentation Basin and then discharged into Outfall 001. The C-613 Sedimentation Basin was designed to collect surface runoff from the scrap metal yards. With the removal of waste from these areas, that source of contamination has been reduced significantly.

Outfall 015 receives surface-water runoff from the east-central sections of the plant. Outfall 017 receives surface-water runoff from the southeast section of the plant (primarily the cylinder storage yards). Outfall 019 receives surface-water runoff from C-746-U (DOE's operational nonhazardous, solid waste landfill) and Outfall 020 receives treated leachate from the C-746-S and C-746-U Landfills. Radiological effluent data are presented in Section 1, Tables 1.1 through 1.5, of Volume II of this report.

Landfill Surface Runoff

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, the C-746-S&T Landfills are monitored as one landfill ("L" locations shown in Figure 4.2). Also, surface runoff is monitored from the operating C-746-U Contained Landfill. Surface runoff from these landfills is monitored for gross alpha and gross beta concentrations. 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 for landfill operations. Sampling data are presented in Section 1, Tables 1.6 through 1.10, of Volume II of this report.

Liquid Effluent Monitoring Results

Table 4.1 indicates the minimum, average, and maximum concentrations of uranium and maximum uranium activity concentrations discharged at each outfall monitoring location for CY 2009. A normal isotopic distribution was assumed during the conversion of uranium concentrations to uranium activities.

Table 4.1. Total Uranium Concentration in DOE Outfalls for CY 2009

Outfall	Number of Samples	Minimum Uranium (mg/L)	Average Uranium (mg/L)	Maximum Uranium (mg/L)	Converted Maximum Uranium Activity (pCi/L)[b]
001	55	0.001	0.028	0.314	213
015	10	0.011	0.114	0.185	125
017	22	0.001	0.002	0.003	2.03
019	14	0.001	0.009	0.019	12.9
020	1	0.007	0.007	0.007	4.75

[a] DCG for uranium is 600 pCi/L.
[b]Maximum uranium concentration was converted to an activity basis by assuming a normal isotopic distribution (99.3% ^{238}U 0.71% ^{235}U and 0.0054% ^{234}U).

Table 4.2 indicates the minimum, average, and maximum ^{99}Tc activity concentrations discharged at each outfall monitoring location for CY 2009. These ^{99}Tc concentrations are well below the DCG of 100,000 pCi/L, and thus protective of human health.

Table 4.2. ^{99}Tc Activity in DOE Outfalls for CY 2009

Outfall	Number of Samples	Minimum (pCi/L)[a]	Average (pCi/L)[a]	Maximum (pCi/L)[a]
001	4	5.78	20.4	38.9
015	4	11.6	21.7	31.9
017	5	1.41	5.70	12.8
019	9	-5.34	9.33	36
020	1	10.9	10.9	10.9

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

5 Radiological Environmental Surveillance

Abstract

The radiological environmental surveillance program assesses the effects of DOE's activities on the surrounding population and environment. Surveillance includes analyses of surface water, groundwater, sediment, terrestrial wildlife, direct radiation, and ambient air. Surveillance results from 2009 indicate that radionuclide concentrations in sampled media were within applicable DOE standards.

Introduction

The Radiological Environmental Surveillance Program at the Paducah Site is based on DOE Orders 450.1A, *Environmental Protection Program,* and 5400.5, *Radiation Protection of the Public and the Environment.* These orders require that an environmental surveillance program be established at all DOE sites to monitor the radiological effects, if any, of DOE activities on the surrounding population and environment. Surveillance includes analyses of surface water, groundwater (Section 9), sediment, terrestrial wildlife, direct radiation, and ambient air. Surveillance results from 2009 indicate that radionuclide concentrations in sampled media were within applicable DOE standards.

Ambient Air

In accordance with the 1993 DOE/USEC lease agreement, USEC is responsible for their radionuclide airborne point-source discharges at PGDP, while DOE is responsible for the NWPGS, the NEPCS, C-752-A waste activities, and DMSA OS-12 waste reduction and packaging activities. Using Kentucky Cabinet for Health and Family Services (KCHFS)-operated air monitors, DOE monitors fugitive emission sources such as building roof tops, piles of contaminated scrap metal, roads, concrete rubble piles, and the decontamination of machinery and equipment used in remediation activities.

DOE utilized ambient air monitoring data to verify radionuclide levels in off-site ambient air. Ambient air samples are collected at 10 sites surrounding the plant (see Figure 5.1) in order to measure the radionuclides emitted from Paducah Site sources, including fugitive emissions. The Radiation/Environmental Monitoring Section of the Radiation Health Branch of the KCHFS's Department for Public Health conducted ambient air monitoring during 2009. There were no DOE unplanned releases in 2009.

The isotopes released are included in the 2009 emissions data for the stack, which are well below the annual limit. The monitoring results for 2009 are listed in Section 2, Table 2.1 of Volume II, of this report.

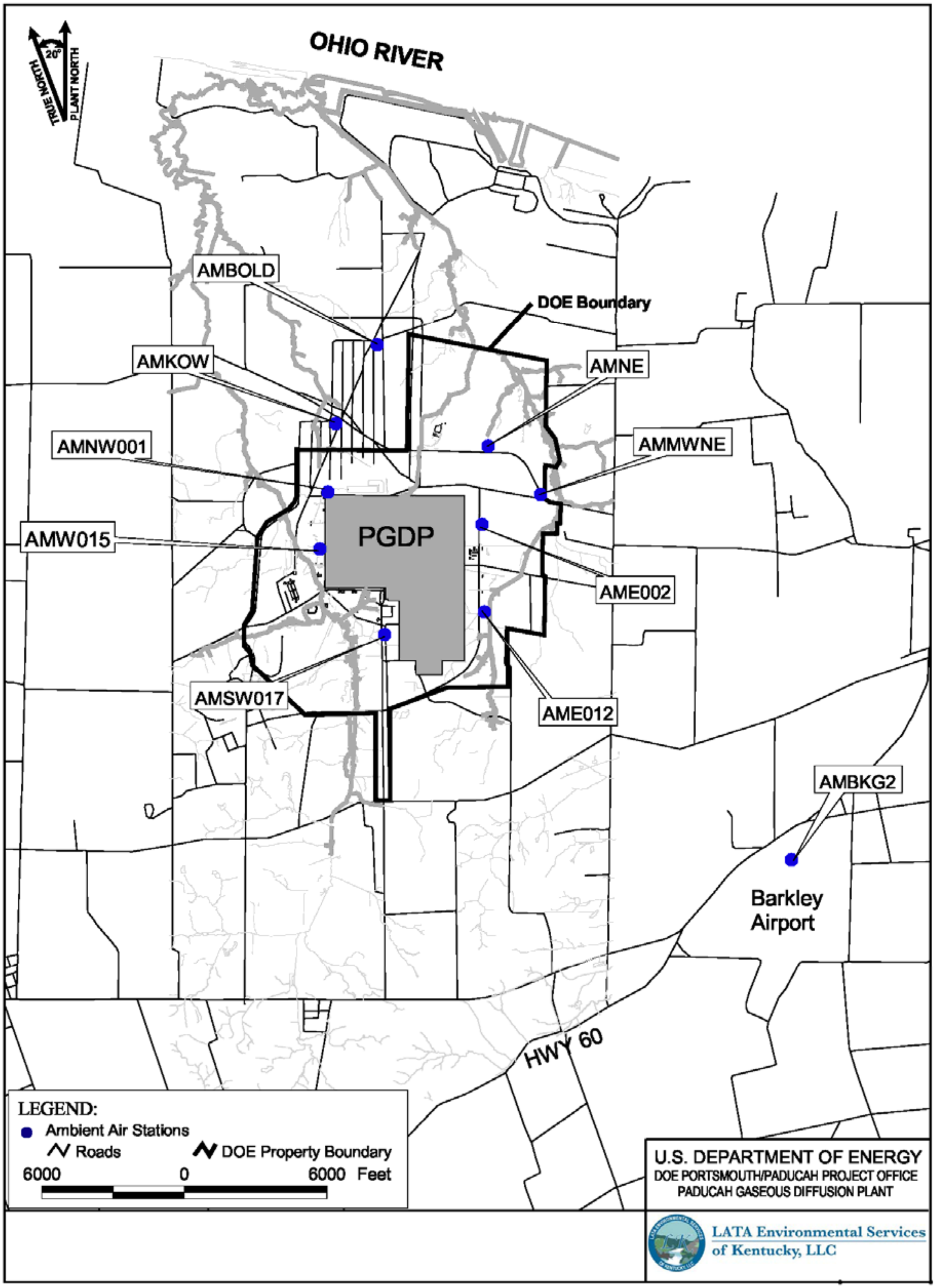

Figure 5.1. Paducah Site Ambient Air Monitoring Stations

Meteorological Monitoring

Computer-aided atmospheric-dispersion modeling uses emission and meteorological data to determine the impacts of plant operations to the community. Modeling is used at the Paducah Site to simulate the transport of air contaminants and 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 to employees and population centers downwind of the source. Historical meteorological monitoring data collected at the site, as well as regional National Weather Service meteorological monitoring data is used in the modeling analysis.

Monitoring Materials for Free Release

In order to ensure compliance with the requirements for unrestricted release found in DOE O 5400.5 Change 2, *Radiation Protection of the Public and the Environment*, a program has been established to regulate the release of materials from radiological and controlled areas. Materials with the potential for surface contamination are assessed by representatives from the Radiological Control organization to ensure that the material meets the limits established in the DOE Order. Depending on the type, volume, design of the material, and the intent of the release, the assessment may include a review of use history, radiological measurements of the surface radioactivity levels (i.e., surveys), and sampling of any internal fluids. Through careful application of this process, projects can successfully release materials from radiological and controlled areas for return to vendors, the public, or for reuse and recycle.

Surface Water

Paducah Site surface water runoff is released through plant outfalls either to the west in Bayou Creek or to the east in Little Bayou Creek. These merge north of the site and discharge into the Ohio River. The net impact of the Paducah Site on surface waters is evaluated by comparing data from samples collected upstream of the site to data from samples collected downstream of the site or from ecologically similar waterways that have not been impacted by PGDP activities. Bayou Creek and Little Bayou Creek are not used as drinking water supplies; therefore, EPA safe-drinking-water standards do not apply. Radioactive effluents from PGDP are managed in accordance with DOE Order 5400.5.

Table 5.1 shows the radiological analytical parameters analyzed under the quarterly surveillance surface water sampling program. The radiological contaminants of concern at PGDP are alpha, beta, and ^{99}Tc.

Table 5.1. Radiological Parameters for Surface Water Samples

Parameter	Parameter
Americium-241 (^{241}Am)	Potassium-40 (^{40}K)
Cesium-134 (^{134}Cs)	Technetium-99 (^{99}Tc)
Cesium-137 (^{137}Cs)	Thorium-228 (^{228}Th)
Cobalt-60 (^{60}Co)	Thorium-230 (^{230}Th)
Dissolved Alpha	Thorium-232 (^{232}Th)
Suspended Alpha	Thorium-234 (^{234}Th)
Dissolved Beta	Uranium (U)
Suspended Beta	Uranium-234 (^{234}U)
Neptunium-237 (^{237}Np)	Uranium-235 (^{235}U)
Plutonium-238 (^{238}Pu)	Uranium-235 (^{235}U) Activity
Plutonium-239/240 ($^{239/240}$Pu)	Uranium-238 (^{238}U)

Figure 5.2 shows 20 surveillance surface water sampling locations and one seep location. Radiological sampling is conducted at the following surface water sampling locations:

- Upstream Bayou Creek (L1);
- Bayou Creek near the plant site (C612, C616, K001UP, K015UP, S31, and L291);
- Downstream Bayou Creek (L5 and L6);
- Little Bayou Creek near the plant site (L10 and L194);
- Downstream Little Bayou Creek (L11, L12, and L241);
- From the C-746-K Landfill (C746K-5 and C746KTB1A);
- Upstream Ohio River (L29);
- Downstream Ohio River (L30);
- Downstream Ohio River at the confluence with the Mississippi River (L306), which is the closest public drinking water supply intake point downstream of the plant;
- Background stream Massac Creek (L64);
- Sampling is also performed at one seep location (an upwelling of groundwater in a stream bed), Downstream Little Bayou Creek Seep (LBCSP5); and
- No sample point exists for upstream Little Bayou Creek because the flow in that part of the watershed is too low to monitor. Nearly all water in Little Bayou Creek is comprised of discharges from plant outfalls; therefore, reference water quality for Little Bayou Creek is based on Bayou Creek at station L1 (upstream Bayou Creek). Data from sampling locations, L129 (Ohio River) and L64 (Massac Creek), also are used as references for water quality in comparison to Little Bayou Creek.

One seep location in Little Bayou Creek (LBCSP5) was sampled for radiological constituents during 2009. Although there have been several locations sampled in the past, two locations were chosen to sample each quarter to trend and observe changes in data; however, one of the seep locations could not be sampled due to high water levels at the sample point. The sampled seep (LBCSP5) is located downstream of the plant site approximately halfway between the site and the Ohio River (see Figure 5.2).

The surface water results are compared to the DCGs, which are the maximum levels that are considered protective of human health and the environment. These levels are given in DOE Order 5400.5. These values are maximum allowable concentrations calculated from the dose of 100 mrem from one isotope and one exposure pathway.

Surface Water Surveillance Results

Table 5.2 provides the average concentrations of radionuclides upstream and downstream of plant effluents in Bayou Creek, downstream of plant effluents in Little Bayou Creek; at the C-746-K Landfill; near the plant site in Bayou Creek and Little Bayou Creek; upstream and downstream in the Ohio River and at the confluence of the Mississippi River (Cairo, Illinois); and at the reference stream, Massac Creek. The table only reflects radionuclide parameters in which at least one sampling location was reported at a concentration greater than the laboratory detection limit; therefore, not all parameters listed in Table 5.1 are cited in Table 5.2. Comparison of downstream data to upstream data and/or reference data is one of the factors used to determine the impact of plant effluents on Little Bayou Creek and Bayou Creek. The radionuclide levels found, that could be referenced to plant operations, were well below their respective

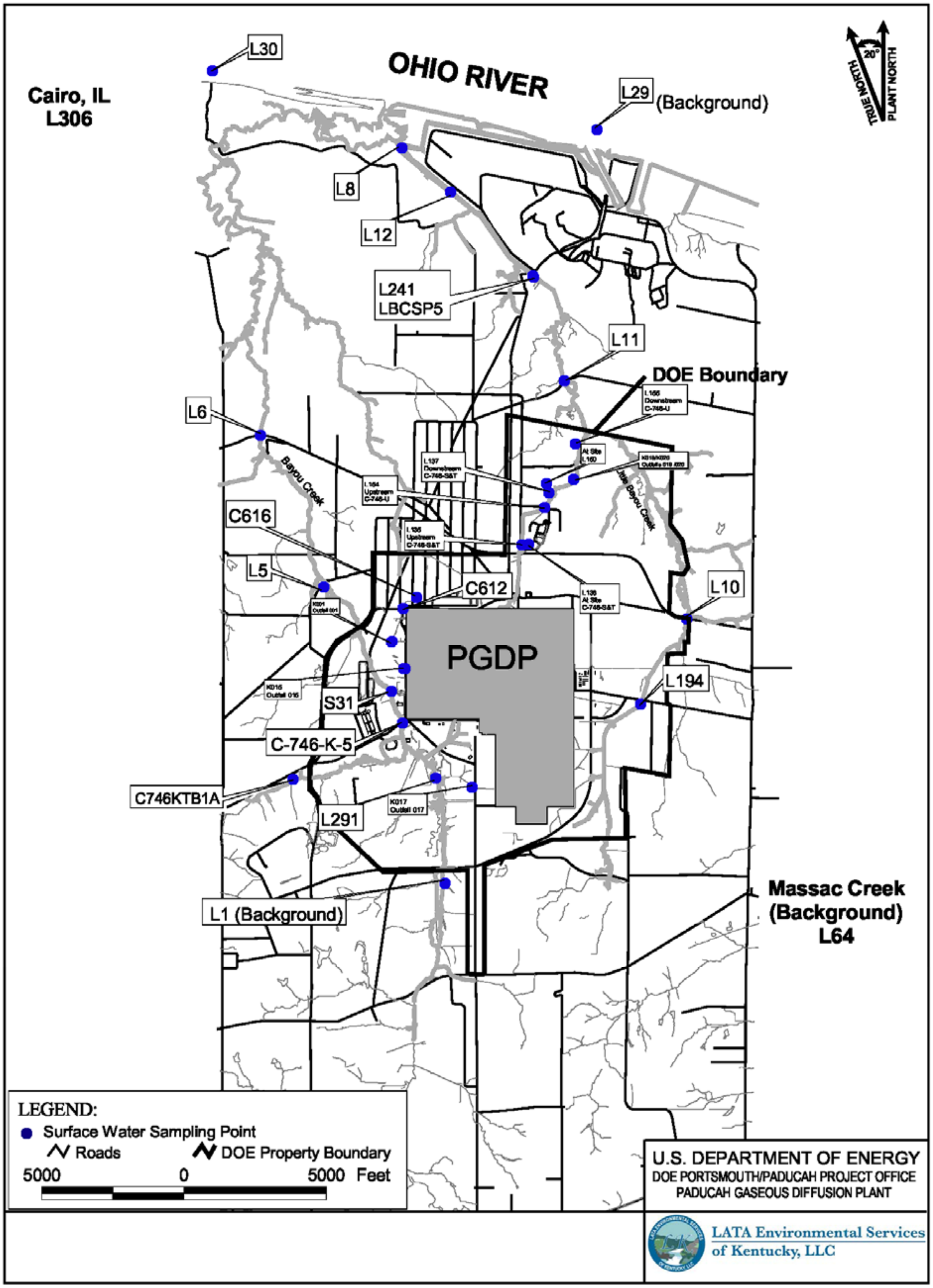

Figure 5.2. Surface Water Monitoring Locations

DCGs. Additionally, although the table is a compilation of averaged data results, it should be noted that only detected concentrations were used in the averaging process. Therefore, there may be instances where the reported average result is the maximum reported result if all other results throughout the year were undetected for a given radionuclide.

Table 5.2. Average Radiological Results for Surface Water Surveillance Samples for CY 2009[a]

Parameter (pCi/L, except where noted)	DCG[b]	Up-stream Bayou[1]	Bayou near Site[2]	Down-stream Bayou[3]	Little Bayou near Site[4]	Down-stream Little Bayou[5]	C-746-K Landfill[6]	Up-stream Ohio[7]	Down-stream Ohio[8]	Cairo, IL[9]	Massac Creek[10]
Activity of U-235	--	ND	0.595	ND	0.112	ND	ND	ND	ND	ND	ND
Cobalt-60	--	ND	ND	ND	ND	ND	ND	2.95	ND	ND	ND
Dissolved Alpha	--	ND	27.7	ND	5.69	ND	ND	ND	ND	ND	ND
Suspended Alpha	--	ND	5.06	ND	ND	5.38	ND	ND	ND	ND	ND
Dissolved Beta	--	ND	27.7	19.2	ND	11.8	9.3	ND	ND	ND	ND
Suspended Beta	--	ND	15.7	ND	ND	ND	ND	ND	10.3	12.8	ND
Neptunium-237		ND	0.201	ND	ND	ND	ND	ND	ND	ND	ND
Potassium-40	7,000	42.9	52.6	53	41.4	ND	43.2	ND	ND	ND	ND
Technetium-99	100,000	ND	23.2	ND	ND	ND	ND	ND	26	ND	ND
Thorium-228	10,000	ND	0.154	ND	0.155	ND	ND	0.079	0.121	0.095	0.129
Thorium-230	10,000	ND	0.285	ND	ND	ND	ND	ND	ND	ND	ND
Thorium-234	10,000	ND	79.6	ND	ND	ND	ND	ND	ND	ND	ND
Uranium (mg/L)	--	ND	0.009	ND	0.007	0.009	ND	ND	ND	ND	ND
Uranium	600	ND	22.3	2.51	4	2.65	ND	ND	ND	ND	ND
Uranium-234	500	ND	5.9	0.785	0.511	0.57	ND	ND	ND	ND	ND
Uranium-235	600	ND	0.567	ND	ND	ND	ND	ND	ND	ND	ND
Uranium-235 (wt %)	--	ND	0.355	ND	ND	0.231	ND	ND	ND	ND	ND
Uranium-238	600	ND	10.8	0.944	2.25	1.74	0.193	ND	0.327	0.16	ND

[a] Average concentration for the seep location (LBCSP5) is found in Table 5.3.
[b] Derived Concentration Guide (see Liquid Effluents section for definition).
-- DCGs for these radionuclides not provided.
ND = not detected
The following footnotes correspond with column titles in the above table. These are groupings of sampling locations in the area described in the title.

1 = L1 (Background)
2 = C612, C616, K001UP, K015UP, L291, S31
3 = L5, L6
4 = L10, L194,
5 = L11, L12, L241
6 = C746KTB1A,C-746-K-5
7 = L29 (Background)
8 = L30
9 = L306
10 = L64 (Background)

Table 5.3 provides the average concentrations of radiological parameters at one seep location, LBCSP 5. Results indicate that the concentration of ^{99}Tc is higher at this seep than at other surface water locations on Little Bayou Creek; however, these concentrations are well below the Northwest Plume Interim Remedial Action target treatment level of 900 pCi/L and the EPA maximum contaminant limit of 900 pCi/L. Additional radiological surface water data are presented in Section 2, Tables 2.2 through 2.22 in Volume II of this report.

Table 5.3. Average Radiological Sample Results for Surface Water Seep Location in Little Bayou Creek for CY 2009

Parameter (pCi/L)	LBCSP5	DCG
Alpha Activity	1.65	--
Beta Activity	76.1	--
Technetium-99	79.8	100,000
Uranium	0.168	600

DCG levels established by DOE Order 5400.5 are screening values for the protection of human health and the environment. Radiological sample results for all surface water and seep location sampled in 2009 were less than DCG levels.

Sediment

Sediment is an important constituent of the aquatic environment. If a pollutant is a suspended solid or attached to suspended sediment, it can settle to the bottom, be taken up by certain organisms, or become attached to plant surfaces. Pollutants transported by water 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 can play a significant role in aquatic ecological impacts by serving as a repository for radioactive or chemical substances that pass via bottom-feeding biota to the higher trophic levels thus creating the need for sediment sampling.

Sediment Surveillance Program

Because DOE retained responsibility for historic environmental issues, ditch sediments are sampled semiannually through a radiological environmental surveillance program. Sediment samples were taken from 14 locations (Figure 5.3). Table 5.4 shows the radiological analytical parameters.

Sediment Surveillance Results

Table 5.5 shows the concentrations of radionuclides in the sediments upstream and downstream of DOE. The sample locations are similar to those of the surface water surveillance program, except for the addition of NSDD, and the deletion of the Ohio and Mississippi Rivers from sediment surveillance (Figure 5.3).

Table 5.5 reflects only radionuclide parameters in which at least one sampling location was reported at a concentration greater than the laboratory detection limit; not all parameters listed in Table 5.4 are cited in Table 5.5. Additionally, although the table is a compilation of averaged data results, it should be noted that only detected concentrations were used in the averaging process. Therefore, there may be instances where the reported average result is the maximum reported result if all other results throughout the year were undetected for a given radionuclide.

In general, S32, within Section 3 of the NSDD, has the highest levels of most radionuclides. Section 3 is outside the security fence (Table 5.5), and access to this area is limited. This area was the subject of a CERCLA investigation, under the Surface Water OU. Excavations began in 2009, and restoration activities will be completed in 2010 to reduce risk to humans and/or the environment (see Chapter 3).

Uranium activity is elevated in Little Bayou Creek and Bayou Creek near the plant site and downstream. The downstream location (S34) on Little Bayou Creek corresponds with the surface water seep site (LBCSP5) previously mentioned.

Other radionuclides, although present, are not significantly above background levels. Additional sediment data are presented in Tables 2.23 through 2.36 in Volume II, Section 2 of this report.

Areas that contain elevated radionuclide levels are controlled within the DOE property boundaries or are posted for protection. Complete annual does estimates can be found in Section 6 of this ASER.

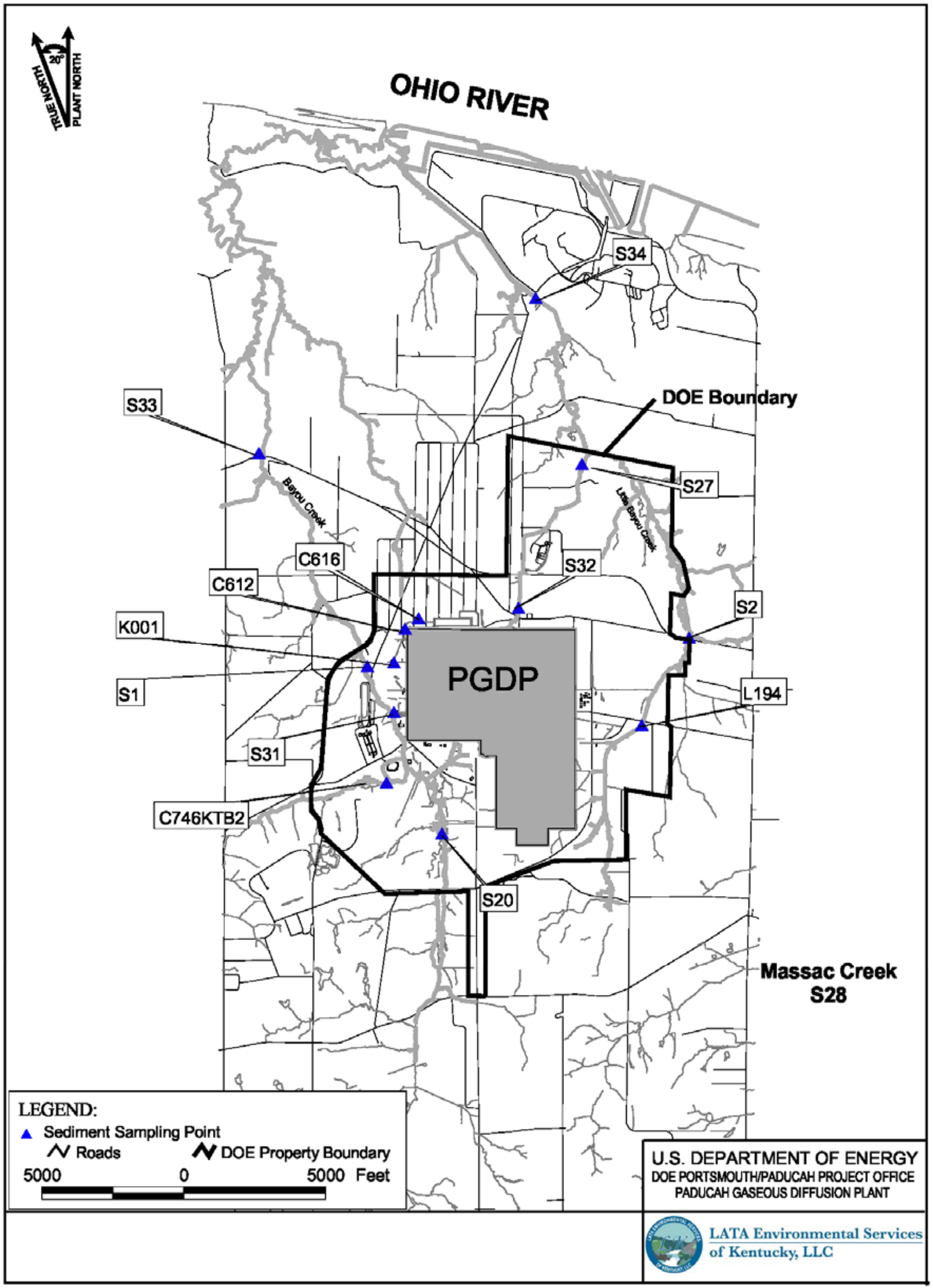

Figure 5.3. Sediment Monitoring Locations

Table 5.4. Radiological Parameters for Sediment Samples

Parameter
Alpha Activity
Americium-241 (^{241}Am)
Beta Activity
Cesium-137 (^{137}Cs)
Cobalt-60 (^{60}Cs)
Neptunium-237 (^{237}Np)
Plutonium-239/240 ($^{239/240}Pu$)
Potassium-40 (^{40}K)
Technetium-99 (^{99}Tc)
Thorium-230 (^{230}Th)
Uranium (U)
Uranium-234 (^{234}U)
Uranium-235 (^{235}U)
Uranium-238 (^{238}U)

Table 5.5. Average[a] Radiological Results for Sediment Surveillance Samples for CY 2009

Parameter	Up-stream Bayou[1]	Bayou Near Site[2]	Down-stream Bayou[3]	Little Bayou Near Site[4]	Down-stream Little Bayou[5]	C-746-K Area[6]	NSDD[7]	Massac Creek[8]
Alpha Activity (pCi/g)	1.95	11.5	4.2	9.42	6.14	2.15	71.9	ND
Americium-241(pCi/g)	ND	0.016	ND	ND	0.025	ND	1.02	ND
Beta Activity (pCi/g)	ND	14.4	5.49	15.2	7.81	2.6	80.3	ND
Cesium-137 (pCi/g)	ND	0.056	0.035	0.032	0.047	ND	0.727	ND
Neptunium-237 (pCi/g)	ND	0.051	ND	0.0125	ND	ND	0.658	ND
Plutonium-239/240 (pCi/g)	ND	0.046	0.009	ND	0.076	ND	3.79	ND
Potassium-40 (pCi/g)	2.60	6.14	5.95	4.49	3.69	2.60	5.6	2.54
Technetium-99 (pCi/g)	2.19	4.28	0.513	0.416	1.39	0.456	9.17	0.224
Thorium-230 (pCi/g)	0.199	0.594	0.249	0.283	1.71	0.197	56.35	0.159
Uranium (pCi/kg)	ND	7360	934	9440	2907	1100	17425	ND
Uranium-234 (pCi/g)	0.119	4.04	0.419	1.07	0.638	0.289	7.26	0.075
Uranium-235 (pCi/g)	ND	0.183	0.021	0.127	0.052	0.0192	0.358	ND
Uranium-235 (wt%)	ND	0.949	0.647	0.257	0.362	0.496	0.608	ND
Uranium-238 (pCi/g)	0.115	3.14	0.494	8.245	2.22	0.351	9.86	0.069

[a] The average within each group of locations.
ND = not detected
The following footnotes correspond with column titles in the above table. These are groupings of sample locations in the area described in the title and are shown on Figure 5.3.

1 = S20 (Background)
2 = C612, C616, K001, S1, S31
3 = S33
4 = S2, L194
5 = S27, S34
6 = C746KTB2
7 = S32
8 = S28 (Background)

Annual Deer Harvest

In 2009, five 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. No reference deer were collected in 2009 due to the availability of sufficient historical data, which were used for comparison. Reference deer historically have been harvested from neighboring counties (e.g., Ballard County, Livingston County). Liver, muscle, and bone samples were analyzed for several radionuclides (^{137}Cs, ^{237}Np, ^{239}Pu, ^{99}Tc, ^{230}Th, $^{233/234}U$, ^{235}U, and ^{238}U). In addition, thyroid samples were analyzed for ^{99}Tc. Because the liver and muscle tissues are considered consumable by humans, these tissues can be evaluated for radiological risks (dose) if analyses reveal detectable levels. Bone and thyroid samples are used only as indicators of contamination.

In 2009, no radionuclides were detected in the liver and muscle tissue of the sampled deer. Additional deer data are presented in Section 2, Tables 2.38 through 2.41 in Volume II of this report. Section 6 of this volume, discusses dose calculations associated with eating deer from the WKWMA.

Direct Radiation

A potential concern from 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 at the Paducah Site include the cylinder storage yards, the operations inside the cascade building, 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 EMP (PRS 2009a; PRS 2009b) established 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:

(1) To establish the radiation dose potentially received by a member of the public from direct exposure to DOE operations at the boundary of the PGDP perimeter fence;

(2) To establish the dose potentially received by a member of the public visiting or passing through accessible portions of the DOE Reservation; and

(3) To calculate the radiation dose equivalent for the maximally exposed individual member of the public.

In 2009, direct radiation was monitored by quarterly placement, collection, and analysis of environmental thermoluminescent dosimeters (TLDs). These monitoring locations are shown in Figure 5.4. Monitoring results indicate that 8 of 42 locations were consistently above background levels (PRS 2010a). These locations were all at or near the PGDP security fence in the vicinity of UF_6 cylinder storage yards in areas not accessible to members of the public.

Annual dose rates for the background locations and eight locations above background were calculated. Based on the analysis of TLDs placed away from DOE property, the mean annual background exposure was determined to be 86 mrem (PRS 2010a). 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 CY 2009 attributed to the Paducah Site (Table 5.6). Exposure measured at these locations is assumed to result from DOE operations. Since all of the locations shown in Table 5.6 are in areas not accessible to the public, dose from direct radiation exposure to the maximally exposed individual from DOE operations is 0.00015 mrem, which is below the applicable DOE limits.

Dose calculations associated with direct radiation exposure are discussed further in Section 6. Additional data are presented in Volume II, Section 2 of this report.

Table 5.6. Net Annual Exposure from Direct Radiation Attributed to the Paducah Site for CY 2009 (mrem)

Location	TLD-1	TLD-2	TLD-3	TLD-25	TLD-47	TLD-48	TLD-50	TLD-53
Total annual exposure	1,001	1,301	326	121	339	181	016	419
Background[a]	86	86	86	86	86	86	86	86
Net annual exposure[b]	915	1,215	240	35	253	95	20	333

[a] Background is calculated based on the analysis of TLDs placed away from DOE property (PRS 2010a).
[b] Locations with net annual exposure from direct radiation above background levels are in areas not accessible to the public.

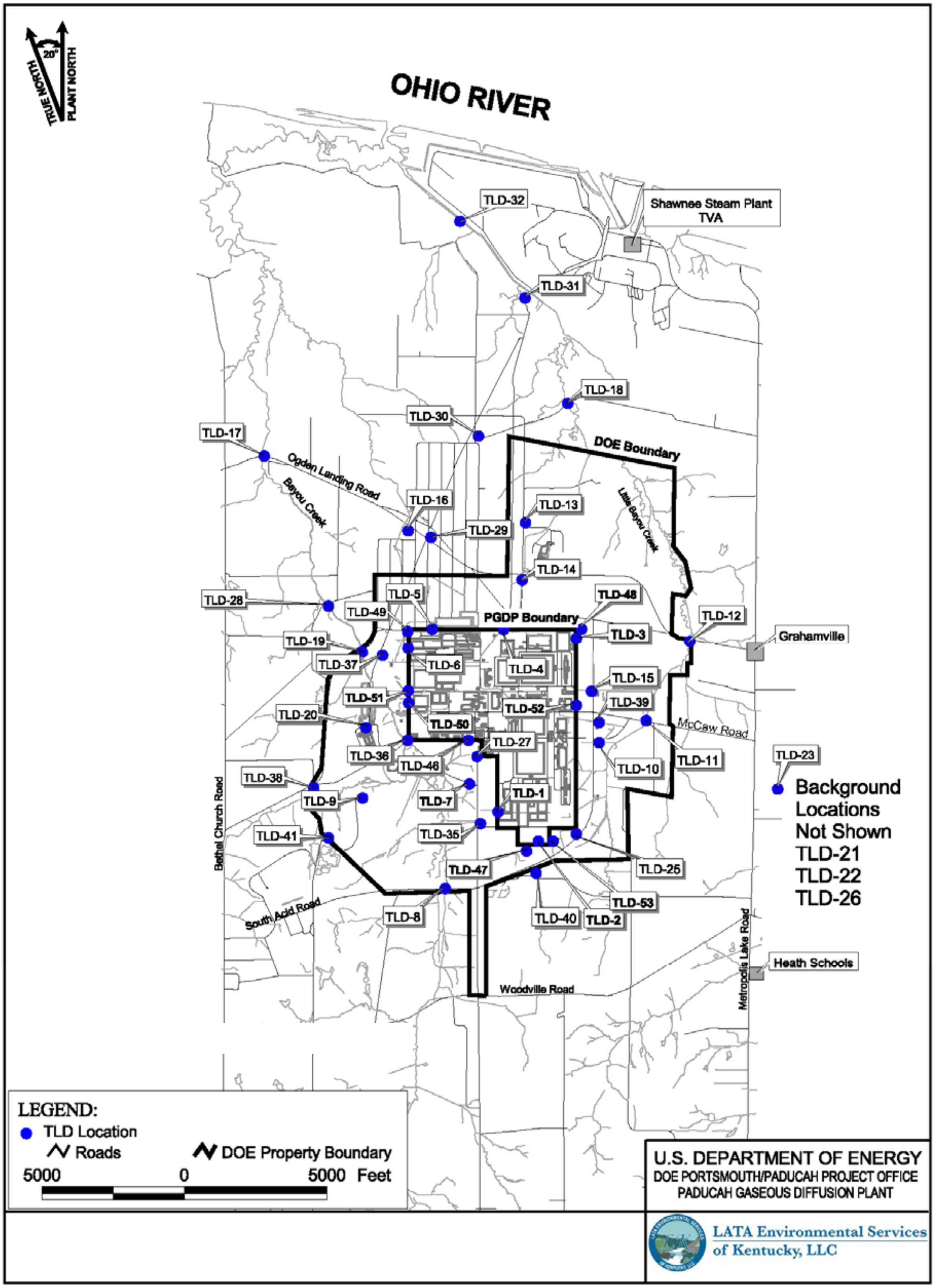

Figure 5.4. TLD Locations in the Vicinity of PGDP

6 Radiological Dose Calculations

Abstract

For 2009, exposure pathways potentially contributing to radiological dose include ingestion of surface water, ingestion of sediments, 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 0.46 mrem per year. This dose is less than 0.5 percent of the applicable federal standard of 100 mrem per year.

Introduction

This section presents the calculated radiological doses to individuals and the surrounding population from atmospheric and liquid releases from the Paducah Site, as well as from direct radiation (Sections 4 and 5). In addition, potential doses from special-case exposure scenarios, such as wildlife meat consumption, were calculated based upon deer sample analyses. Doses from naturally occurring sources are discussed in Appendix A. The highest estimated dose that a maximally exposed individual might have received from all combined DOE exposure pathways (worst-case scenario) was 0.46 mrem per year. This dose is less than 0.5 percent of the applicable federal standard of 100 mrem per year.

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 per 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 was used to develop exposure pathways of concern. On-site operations were used to determine which radionuclides to evaluate.

An early preliminary assessment of risk to public health from contaminants at the Paducah Site identified the following four primary exposure routes, each of which could contribute at least 1 percent to the total off-site dose: (1) groundwater ingestion, (2) sediment ingestion, (3) wildlife ingestion, and (4) exposure to direct radiation. Since that preliminary assessment, groundwater wells that supplied drinking water downgradient from PGDP have been replaced with public drinking water, resulting in the loss of that exposure route. A drinking water pathway for consumption of surface water at the nearest public drinking water source [Ohio River at Cairo, Illinois (L306)] is included in dose calculations. Surface water is not used for drinking water in the PGDP area. Initiation of the NWPGS and the NEPCS resulted in another airborne pathway that is included in the dose calculations. In 2006, the C-301 DMSA OS-12 activities were added to the airborne dose and it remained a contributing factor in 2009 as well. Waste management activities at the C-752-A Building were added in 2008 and continued in 2009.

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

Terminology and Internal Dose Factors

Most of the human health 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 and can result in tissue damage. Radiation may come from radionuclides outside the body 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 radionuclide; simply leaving the area of the source will stop the exposure. Internal exposure continues as long as the radionuclide remains inside the body.

Damage associated with exposures to radiation results primarily from the deposition of radiant energy in tissue. The exposure is defined in terms of the amount of incident radiant energy absorbed by tissue and the biological consequences of that absorbed energy. These terms or quantities 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 one-year period. The CEDE is the product of the annual intake (pCi) and the dose conversion factor for each radionuclide (mrem/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 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.

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 CEDE estimate resulting from the intake. Internal dose factors for several radionuclides of interest at the Paducah Site are included in Appendix A.

Landfill Authorized Limits

DOE Authorized Limits were established for the landfill in July 2003 under DOE Order 5400.5. The limits are based on conservative modeling to assure that the annual dose to workers will not exceed 2.1 mrem per year. Other users of the reservation area around the landfill site and members of the public will not receive more than 1 mrem of additional radiation per year as a result of landfill operations. The authorized limits apply to the disposal of soil, metal, and debris wastes into the C-746-U Landfill generated from construction, maintenance, environmental restoration, and D&D activities at the PGDP. During 2009, approximately 700 tons of authorized limits waste was shipped to the C-746-U Landfill. No exposure above background radiation was detected in the landfill workers. Table 6.1 presents the 6th year authorized limits inventory (in Curies) dispositioned to the landfill and the total cumulative inventory dispositioned to the landfill since 2003.

Table 6.1. Summary of Authorized Limits Waste Disposed in C-746-U Landfill

	6th Year Inventory (5/22/08 to 5/21/09)			Total Inventory (5/21/03 to 5/21/09)		
Isotope	**Activity (Curies)**	**Annual Inventory Allowed (Curies)**	**% Inventory Used**	**Activity (Curies)**	**Total Inventory Allowed (Curies)**	**% Inventory Used**
Americium-241	0.0000249	0.021	0.12%	0.0051841	0.155	3.34%
Cesium-137	0.0000624	0.021	0.30%	0.0044103	0.155	2.85%
Neptunium-237	0.0001222	0.021	0.58%	0.0096630	0.155	6.23%
Plutonium-238	0.0000167	0.021	0.08%	0.0010222	0.155	0.66%
Plutonium-239/240	0.0000495	0.021	0.24%	0.0092259	0.155	5.95%
Technetium-99	0.0138277	3.5	0.40%	0.8108796	25.8	3.14%
Total Thorium	0.0004082	0.105	0.39%	0.2883286	0.825	34.95%
Total Uranium	0.0100355	1.05	0.96%	0.2661607	7.75	3.43%

Direct Radiation

In 2009, DOE conducted continuous monitoring for direct external radiation exposure (Section 5). Access to PGDP is limited due to the increased boundary security implemented in September 2001. The monitoring results indicate that dose to the neighbor living closest to the PGDP security fence did not vary statistically from background because of the limited access of the public to radioactive material areas (PRS 20010a).

For purposes of this ASER, an additional potential receptor was considered. In a conservative exposure scenario, this receptor is assumed to be exposed to the location at TLD-14 for 8.3 hours for the year. TLD-14 is near Harmony Cemetery, located north of the plant security fence and south of Ogden Landing Road (Figure 5.4). The 8.3 hours-per-year assumption is based on an individual driving past this location twice per day at 1 minute per trip, five days per week, 50 weeks per year. It is likely that actual exposure at this location is probably less than that assumed because shielding from the receptor's vehicle was not considered. This location's total annual exposure was 74 mrem and resulted in a calculated hypothetical external radiation exposure that is below background level of 86 mrem. Thus, based on results from this location and other data obtained from all locations, the dose to the maximally exposed individual from DOE operations was estimated at 0 mrem/year, below the applicable DOE limits.

Surface Water

The most common surface water exposure pathway is through drinking water containing radionuclides. Surface water pathway dose was calculated for an individual assumed to consume water from the public drinking water supply at Cairo, Illinois (L306). Cairo is the closest drinking water system (approximately 30 miles downstream) that uses water downstream of PGDP effluents. Cairo is located at the confluence of the Ohio and Upper Mississippi Rivers. The average concentrations of radionuclides that were detected near the surface water collection inlet at Cairo were used to calculate the exposure resulting from consumption of surface water.

As shown in Table 5.2, ^{228}Th and ^{238}U were detected in Cairo at an average concentration of 0.095 pCi/L and 0.16 pCi/L, respectively. These results are well below their respective DCG levels of 400 pCi/L and 600 pCi/L. Although ^{238}U is an alpha emitter, no detectable concentrations of total alpha activity was reported at Cairo. Other sources of ^{238}U other than the Paducah Site may attribute to the concentrations reported at Cairo.

For the dose calculation from these isotopes, the maximally exposed individual was assumed to consume all of his/her daily required water, 8 glasses, each containing 8 ounces (a total of approximately 2 L), 365 days a year from the public drinking water supply. The maximum dose to an individual, without subtracting the background dose, was determined to be 0.057 mrem in 2009, which is significantly less than the 100 mrem allowed by DOE Order 5400.5.

Contaminated Sediment

Exposure to contaminated sediment in Bayou Creek and Little Bayou Creek 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 adult individual would splash around in one of the creeks every other day during the season and ingest a small amount of sediment each visit (50 mg/day). A dose then is calculated based on the radionuclide concentrations and the amount of exposure via ingestion. Massac Creek 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.

Doses are calculated for ingestion of sediments for both Bayou Creek and Little Bayou Creek. The worst-case dose was calculated to be at S32, the NSDD (Figure 5.3). The estimated worst case dose above background from sediment ingestion was 0.387 mrem in 2009. This exposure pathway is by far the major contributor to the worst-case combined exposure to the public, and it is significantly less than the DOE annual dose limit of 100 mrem/year. Dose results for all locations are provided in Table 6.2.

Table 6.2 Annual Dose Estimates for CY 2009 Incidental Ingestion of Sediment from Bayou Creek and Little Bayou Creek

Location	Committed Effective Dose Equivalent (mrem)										Total (mrem)
	^{241}Am	^{137}Cs	^{237}Np	$^{239/240}$Pu	^{40}K	^{99}Tc	^{230}Th	^{234}U	^{235}U	^{238}U	
S1	--	1.55E-05	8.94E-04	5.59E-06	5.37E-04	5.96E-05	1.22E-03	2.46E-03	1.29E-04	3.75E-03	9.07E-03
S2	--	--	3.90E-04	--	7.48E-04	3.45E-06	1.37E-03	3.37E-03	3.92E-04	2.56E-02	3.19E-02
S20	--	--	--	--	4.42E-04	2.93E-05	1.00E-03	3.11E-04	--	2.68E-04	2.05E-03
S27	7.43E-04	1.07E-05	--	2.56E-05	4.76E-04	2.05E-05	5.81E-03	1.14E-03	8.52E-05	3.70E-03	1.20E-02
S28 (Bkgd)	--	--	--	--	4.32E-04	2.03E-06	5.86E-04	1.96E-04	--	1.17E-04	1.33E-03
S31	4.60E-04	3.29E-05	1.08E-03	4.88E-05	9.57E-04	1.44E-05	5.36E-03	2.56E-02	9.79E-04	9.67E-03	4.42E-02
S32 (Max)	3.40E-02	3.32E-04	2.67E-02	1.80E-03	9.52E-04	1.23E-04	2.82E-01	1.88E-02	8.71E-04	2.30E-02	3.89E-01
S33	--	1.60E-05	--	3.10E-06	1.01E-03	3.21E-06	1.25E-03	1.09E-03	5.16E-05	1.15E-03	4.58E-03
S34	9.46E-04	3.21E-05	--	4.69E-05	7.78E-04	1.67E-05	1.13E-02	2.18E-03	1.70E-04	6.61E-03	2.21E-02
C612	--	3.70E-05	1.84E-03	1.38E-05	1.41E-03	3.58E-05	2.54E-03	7.91E-03	4.19E-04	1.08E-02	2.50E-02
C616	--	1.37E-05	4.31E-03	1.90E-05	1.09E-03	8.02E-05	2.32E-03	5.78E-03	2.77E-04	6.68E-03	2.06E-02
C746KTB2	--	--	--	--	4.42E-04	3.21E-06	9.87E-04	7.49E-04	2.80E-05	8.18E-04	3.03E-03
L194	--	7.77E-06	--	--	7.78E-04	5.74E-06	1.46E-03	2.20E-03	2.32E-04	1.29E-02	1.75E-02
K001	--	1.87E-05	1.30E-03	9.48E-06	1.27E-03	8.96E-05	2.20E-03	3.09E-03	1.57E-04	4.52E-03	1.26E-02
Net Exposure from Paducah Site to maximally exposed individual[a] (S32 – S28) =											0.387

-- not detected
[a] Maximum allowable exposure is 100 mrem/year for all contributing pathways (DOE Order 5400.5).

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 CEDE estimate resulting from the intake.

Terrestrial wildlife, such as deer, can come into contact with contaminated soil, ingest contaminated plants through contaminant uptake or airborne deposition, 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 (approximately 100 pounds of meat and five pounds of liver). The dose is calculated for each deer sampled.

In 2009, five deer from the Paducah Site were sampled; no radionuclides were detected in either liver or muscle. The dose contribution from deer ingestion is assumed to be 0 mrem/year.

Airborne Radionuclides

DOE had four radionuclide airborne point sources that contributed to the public dose in 2009. These sources were the NWPGS, the NEPCS, the waste activities at C-752-A, and C-301 DMSA OS-12. The four point sources were discussed in Section 4. These point-sources were reviewed or monitored to determine the extent to which the general public could be exposed and to demonstrate compliance with EPA regulations.

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. EPA-supplied CAP-88 software was used to calculate the off-site dose from PGDP air emissions. This software provides a framework for developing dose and risk assessments for the purpose of demonstrating compliance with 40 *CFR* § 61.93(a). It assesses both collective populations and maximally exposed individuals. The dose to the maximally exposed individual for the plant from DOE radioactive air emissions was calculated to be 0.00015 mrem. The maximally exposed individual from all plant emissions is located 2,040 m north of the C-400 group source (a USEC source). The dose from both DOE and USEC emissions is estimated to be 0.012 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 radiological dose for 2009 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 sediment. The groundwater pathway from DOE sources is assumed to contribute no dose to the population because DOE has supplied all residents with public water. The worst-case combined (internal and external) dose to an individual member of the public was calculated at 0.46 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 airborne dose to the public.

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 ICRP Publication 30 (ICRP 1980). Figure 6.1 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 CY 2009 (Worst-Case Combined Exposure Pathways)

Pathway	Dose[a] (mrem/year)	Percent of total
Ingestion of surface water	0.057	13
Ingestion of sediments	0.387	87
Ingestion of deer meat	0	0
Direct radiation	0	0
Atmospheric releases [b]	0.012	0
Total annual dose above background (all pathways)	**0.46**	**100**

[a] Maximum allowable exposure is 100 mrem/year (DOE Order 5400.5).
[b] DOE source emissions were from NWPGS, NEPCS, C-752-A waste activities, and DMSA OS-12.

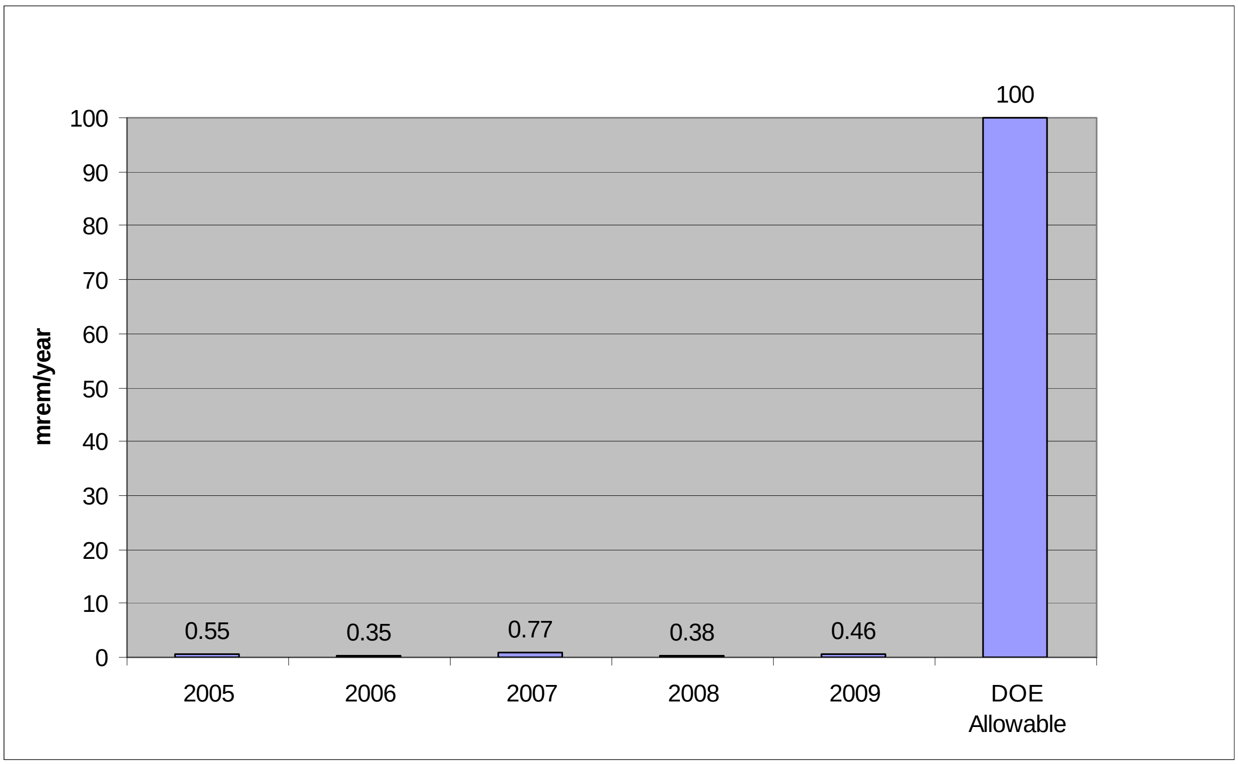

Figure 6.1. Potential Radiological Dose from Activities at the Paducah Site, 2005–2009

7 Nonradiological Point Source Effluent Monitoring

Abstract

Liquid effluent monitoring was conducted at the DOE permitted outfalls and at landfill surface water runoff locations. Compliance with KPDES permit effluent limits was maintained in 2009. DOE had two point sources and several fugitive sources for nonradiological air emissions.

Introduction

Responsibility for nearly all nonradioactive airborne emission sources at 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, soil piles (resulting from construction excavation), and two point sources, remained the responsibility of DOE in 2009. 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 EMP (PRS 2009a; PRS 2009b) and is based on KPDES Permit KY0004049 and KDWM landfill permits SW07300014, SW07300015, and SW07300045. Effluents are monitored for nonradiological parameters listed on the permit.

Nonradiological Airborne Effluents

Airborne Effluent Applicable Regulations

The KDAQ administers much of the CAA at the Paducah Site. 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 point sources of air emissions other than radionuclides (Section 4) for the Paducah Site in 2009 were the NWPGS and the NEPCS. These systems combined removed approximately 1,300 pounds of TCE, which is a VOC and HAP, from approximately 155,000,000 gal of groundwater. These facilities remove TCE contamination from the groundwater by air stripping. At the NWPGS, TCE-laden air passes through activated carbon to remove TCE. The air stream then is released to the atmosphere where any remaining TCE naturally breaks down. The NEPCS uses the existing C-637-2A Cooling Tower at PGDP for stripping the TCE from groundwater. The NWPGS and NEPCS facilities operated in compliance with CERCLA decision documents during 2009.

Nonradiological Liquid Effluents

Liquid Effluent Applicable Regulations

At the Paducah Site, the CWA regulations were applied through issuance of a KPDES permit for effluent discharges to Bayou Creek and Little Bayou Creek. The KDOW issued KPDES Permit No. KY0004049 to the Paducah Site on September 29, 2006. This permit applies to the following four DOE outfalls: 001, 015, 017, and 019.

Following the issuance of the permit, several parties petitioned KDOW for a hearing on the permit. An Order to Mediate was issued by the Kentucky Environmental and Public Protection Cabinet (now named the Kentucky Energy and Environment Cabinet).

An AO settled all parties' disputes with the permit on December 7, 2007. A revised KPDES permit incorporating the changes set forth in the AO was issued on November 4, 2009, and became effective December 1, 2009. This modified permit added an additional outfall (020) to the monitoring locations for separate tracking and monitoring for treated leachate discharges from the C-746-U and C-746-S Landfills.

The KPDES permit calls for chemical monitoring and toxicity monitoring as an indicator of discharge-related effects in the receiving streams. Biological monitoring was not required under the specifications listed in the renewed KPDES permit. Additionally, the watershed monitoring plan was revised to reflect the changes in the renewed permit as is further discussed in Section 9 of the ASER. The renewed permit is set to expire on October 31, 2011.

The KDWM specifies in landfill permits SW07300014, SW07300015, and SW07300045 that surface runoff will 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 (Section 4, Figure 4.2). Outfalls 001, 015, 017, 019, and 020 were monitored for KPDES permit parameters. The specific sample collection, preservation, and analytical methods acceptable for the types of constituents analyzed are listed in the permit and applicable regulations. The KPDES permit is available at the EIC, Barkley Centre, 115 Memorial Drive, in Paducah, Kentucky, for review by the public. Permit analytes and physical measurements are listed in Table 7.1. In this table, some results are not available for all parameters. This is signified by a descriptor of NR meaning that the result was "not reported" because that parameter was not required at that particular location; therefore, a sample was not collected. The ND acronym signifies that the concentration was less than the laboratory reporting limit; therefore, the result was considered "not detected."

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 chemical oxygen demand, chloride, conductivity, dissolved oxygen, total dissolved solids, flow rate, total iron, hydrogen-ion concentration (pH), sodium, sulfate, total suspended solids, temperature, total organic carbon, and total solids. Two sets of samples are collected; one set for the C-746-U and one set for the C-746 S&T Landfills. 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 (Section 4, Figure 4.2). Sampling was performed in compliance with the KDWM requirements for operation of the contained landfill.

Table 7.1. KPDES Effective Permit Sampling Routine Nonradiological Maximum Detected Analyses for CY 2009

Parameter	Permit Discharge Limits During 2009	K001	K015	K017	K019	K020
1,1,2,2,-Tetrachloroethane, µg/L	Report	ND	ND	ND	ND	NR
1,1-Dichloroethene, µg/L	Report	ND	ND	ND	ND	NR
1,1,1-Trichloroethene, µg/L	Report Avg-200d	NR	NR	NR	NR	ND
1,2-Diphenylhydrazine, µg/L	Report	ND	ND	ND	ND	NR
2,4,6-Trichlorophenol, µg/L	Report	ND	ND	ND	ND	NR
2,4-Dinitrotoluene, µg/L	Report	ND	ND	ND	0.202	NR
3,3'-Dichlorobenzidine, µg/L	Report	ND	ND	ND	ND	NR
4,4'-DDD, µg/L	Report	0.004	ND	0.001	0.005	NR
4,4'-DDE, µg/L	Report	0.015	ND	ND	0.002	NR
4,4'-DDT, µg/L	Report	0.006	0.0022	ND	0.004	NR
4-Methylphenol, µg/L	Report	NR	NR	NR	ND	NR
Acrylonitrile, µg/L	Report	0.025	ND	ND	ND	NR
Aldrin, µg/L	Report	0.003	ND	ND	ND	NR
alpha-BHC, µg/L	Report	ND	0.007	0.0116	ND	NR
alpha-Chlordane, µg/L	Report	0.013	0.005	0.0031	0.010	NR
alpha-Terpineol, µg/L	Report	NR	NR	NR	ND	NR
Ammonia as Nitrogen, mg/L	Avg-3.36a/Max-10a	NR	NR	NR	ND	NR
Arsenic, mg/L	Avg-0.150d	NR	NR	NR	NR	ND
Benz(a)anthracene, µg/L	Report	0.02	0.003	ND	0.002	NR
Benzidine, µg/L	Report	0.15	0.029	0.016	ND	NR
Benzo(a)pyrene, µg/L	Report	ND	ND	ND	ND	NR
Benzo(k)fluoranthene, µg/L	Report	0.004	ND	ND	ND	NR
Benzoic acid, µg/L	Report	NR	NR	NR	7.4	NR
beta-BHC, µg/L	Report	ND	0.017	0.0088	0.003	NR
Biochemical Oxygen Demand, mg/L	Report	NR	NR	NR	10	NR
C-Biochemical Oxygen Demand, mg/L	Report	NR	NR	NR	NR	ND
Bis(2-ethylhexyl)phthalate, µg/L	Report	0.36	2.8	2.1	0.59	NR
Cadmium, mg/L	Report	0.000046	0.000082	0.000018	0.000036	NR
Carbon Tetrachloride, µg/L	Report	ND	ND	ND	ND	NR
Chloride, mg/L	Avg-600d/Max-1200d	NR	NR	NR	NR	26
Chloride, Total Residual, mg/L	Avg-.011/Max-.019	0.03	NR	NR	NR	NR
Chrysene, µg/L	Report	0.015	ND	ND	ND	NR
Conductivity, umho/cm	-	1850	1420	600	1320	308
Copper, mg/L	Report	0.007	0.004	0.001	0.002	NR
Cyanide, mg/L	Report	0.006	ND	ND	0.029	NR
Dibenz(a,h)anthracene, µg/L	Report	0.035	ND	ND	ND	NR
Dieldrin, µg/L	Report	0.011	0.003	0.003	0.004	NR
Dissolved Oxygen, mg/L	-	12.4	11.2	10.7	11.4	8.93
Endosulfan I, µg/L	Report	0.018	0.002	ND	0.006	NR
Endosulfan II, µg/L	Report	ND	ND	0.006	ND	NR
Endrin, µg/L	Report	0.005	ND	0.006	ND	NR
Flow Rate, mgd	Report	4.79	4.63	3.37	0.86	0.15
gamma-Chlordane, µg/L	Report	0.019	0.0654	0.003	0.006	NR
Hardness—Total as CaCO3, mg/L	Report	370	260	230	530	330
Heptachlor, µg/L	Report	0.053	0.0137	0.013	0.007	NR
Heptachlor epoxide, µg/L	Report	0.009	ND	0.002	0.004	NR
Hexachlorobenzene, µg/L	Report	ND	ND	ND	ND	NR
Hexachloroethane, µg/L	Report	ND	ND	ND	0.066	NR
Indeno(1,2,3-cd)pyrene, µg/L	Report	0.01	ND	ND	ND	NR
Iron, mg/L	Report	NR	2.06	NR	0.356	2.1
Lead, mg/L	Report	0.0005	0.001	0.0008	0.0003	NR
Lindane, µg/L	Report	0.002	0.004	0.0078	0.001	NR
Mercury, mg/L	Report	0.00002	0.00001	0.000002	0.000002	NR
Nickel, mg/L	Avg-0.094d	NR	NS	NR	NR	0.010
N-Nitrosodimethylamine, µg/L	Report	ND	ND	ND	ND	NR
N-Nitroso-di-n-propylamine, µg/L	Report	ND	ND	ND	ND	NR

Table 7.1. KPDES Effective Permit Sampling Routine Nonradiological Maximum Detected Analyses for CY 2009 (Continued)

Parameter	Permit Discharge Limits During 2009	K001	K015	K017	K019	K020
N-Nitrosodiphenylamine/Diphenylamine, µg/L	Report	ND	ND	ND	ND	NR
Oil and Grease, mg/L	Avg-10/Max-15	ND	ND	ND	ND	ND
Nitrate as Nitrogen, mg/L	Avg-500d	NR	NR	NR	NR	2.5
Polychlorinated biphenyls, µg/L	Avg-0.000065	ND	ND	ND	ND	ND
Pentachlorophenol, µg/L	Report	ND	ND	ND	ND	NR
pH, std unit	6.0<pH<9.0	8.34	8.03	7.98	7.8	8.13
Phosphorous, mg/L	Avg-1.0/Max-1.0	0.62	NR	NR	NR	0.19
Selenium, mg/L	Report	0.0033	0.0016	0.00082	0.0016	NR
Silver, mg/L	Report	ND	ND	ND	ND	NR
Suspended Solids, mg/L	Avg-30b/Max-60b	52	87	16	25	ND
Temperature, °F	89°F	81.5	72.9	76.6	85.5	44.6
Tetrachloroethene, µg/L	Report	ND	ND	ND	ND	NR
Thallium, mg/L	Report	ND	ND	ND	ND	NR
Trichloroethene, µg/L	Avg-30.8	ND	NR	NR	NR	ND
Uranium, mg/L	Report	.314	.185	0.003	0.019	0.007
Zinc, mg/L	Avg-0.12c/Max-0.12c Avg-0.216d/Max-0.216d	NR	ND	0.211	0.033	ND

[a] Per the Agreed Order, these limits have been stayed until new permit was issued (December 2009).
[b] Per the Agreed Order, these limits have been stayed for K001, K015, and K017 until new permit was issued (December 2009).
[c] Per the Agreed Order, these limits have been stayed for K017 until new permit was issued (December 2009). The limit for K019 is Report.
[d] Revised permit effective December 2009 revised the limit.
ND = not detected
NR = not reported/collected. Parameter was not required by the permit at this location.
-- = A permit limit was not established during 2009 for this parameter; however, monitoring was required for this parameter.

Liquid Effluent Monitoring Results

Analytical results from the five DOE outfalls are reported to KDOW in monthly and quarterly discharge monitoring reports. As stated above, the monitoring results for the outfalls are listed in Table 7.1.

Data for the KPDES samples and the surface runoff samples from the landfills are presented in Section 3, Tables 3.1 through 3.10 of Volume II of this report.

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 other aquatic life. Surveillance results for 2009 were similar to results reported in previous ASERs.

Introduction

Nonradiological surveillance at the Paducah Site involves the sampling and analysis of surface water, groundwater, sediment, soil, terrestrial wildlife, and benthic macroinvertebrate. This section discusses the nonradiological results of surveillance activities. Surveillance results were compared to the data obtained from the background locations, as well as historical results for trending purposes.

Ambient Air

As a result of the transfer of the operations of the plant to USEC in 1993, major air emission sources were transferred to USEC; therefore, DOE does not conduct ambient air monitoring for nonradiological parameters at the Paducah Site.

Surface Water

Surface water monitoring (except for toxicity 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. Figure 5.2 shows surveillance surface water sampling locations. Table 8.1 shows the analytical parameters that are analyzed on a quarterly or semiannual basis.

As described in Section 5, seep locations in Little Bayou Creek were added to the surface water sampling program in 2002. These locations, known as seeps, are upwellings of groundwater in the Little Bayou Creek bed. Although there have been several locations sampled in the past, two location were chosen to sample each quarter to trend and observe changes in data. These quarterly sampling events are dependant on conditions at the seep location. During times of high water, obtaining an accurate sample is not possible. The sampled seep (LBCSP5) is downstream of the plant site approximately halfway between the site and the Ohio River (see Figure 5.2). Table 8.1 does not apply to the quarterly seep locations. A different list of analytical parameters is analyzed for the seep, as presented in Table 8.2.

Table 8.1. Nonradiological Parameters for Surface Water Samples

Parameters	
Aluminum	Manganese
Ammonia	Mercury
Antimony	Nickel
Arsenic	Nitrate/Nitrite as Nitrogen
Barium	Alkalinity
Beryllium	PCB Aroclors
Cadmium	pH
Calcium	Phosphorous
Chloride	Polychlorinated Biphenyl, Total
Chromium	Potassium
Cobalt	Selenium
Conductivity	Silver
Copper	Sodium
Cyanide	Suspended Solids
Dissolved Oxygen	Temperature
Flow Rate	Thallium
Hardness	Trichloroethene
Iron	Uranium
Lead	Vanadium
Magnesium	Zinc

Table 8.2. Nonradiological Parameters for Surface Water Seep Sample Location

Parameters	
Chloride	1,1-Dichloroethene
Sulfate	1,2-Dichloroethane
Alkalinity	1,2-Dimethylbenzene
Conductivity	Benzene
Dissolved Oxygen	Bromodichloromethane
pH	Carbon Tetrachloride
Temperature	Chloroform
Calcium	*cis*-1,2-Dichloroethene
Magnesium	Ethylbenzene
Manganese	m,p-Xylene
Potassium	Tetrachloroethene
Sodium	Toluene
1,1,1-Trichloroethane	*trans*-1,2-Dichloroethene
1,1,2-Trichloroethane	Trichloroethene
1,1-Dichloroethane	Vinyl Chloride

Surface Water Surveillance Results

Table 8.3 shows a water chemistry comparison between upstream and downstream locations associated with the plant by presenting the average of maximum concentrations of selected parameters. Selected parameters include only the parameters in which at least one result was reported above the laboratory detection limits.

Reportable concentrations of TCE were detected in background samples. Since TCE was a commonly used solvent in industrial settings, it is not a contaminant considered to be solely associated with the site. Though TCE was reported at some of the surface water sample locations, only the sample collected downstream on Little

Bayou Creek was reported at a concentration greater than the background value. The maximum average concentration at this site was 16.6 microgram per liter (µg/L), which is lower than previous reporting years.

Table 8.3. Selected Routine Nonradiological Surface Water Surveillance Results (Average of Maximum Results) for CY 2009[a]

Parameter (mg/L) except where noted	Up-stream Bayou[1]	Bayou near Site[2]	Down-stream Bayou[3]	Little Bayou near Site[4]	Down-stream Little Bayou[5]	C-746-K Landfill[6]	Up-stream Ohio[7]	Down-stream Ohio[8]	Massac Creek[9]	Cairo, IL[10]
Alkalinity	13.7	17.5	13.4	14.8	15.5	14.8	16.7	17.8	12.8	13.7
Aluminum	0.866	2.83	0.739	1.70	3.49	2.57	6.30	6.29	0.578	4.74
Ammonia Nitrogen	ND	1.18	0.14	0.1	0.26	0.14	0.135	0.18	0.1	
Arsenic	ND	0.012	ND	ND	ND	ND	ND	ND	ND	ND
Barium	0.050	0.145	0.045	0.054	0.079	0.054	0.087	0.080	0.049	0.065
Beryllium	ND	ND	ND	ND	ND	ND	0.001	ND	ND	ND
Calcium	15.9	142	49.3	20.4	35.5	22.1	33.7	34.7	13.5	39.4
Chloride	9.4	230	68.2	23.3	24.4	16.4	11.575	11.3	11.4	19.5
Cobalt	ND	0.001	ND	ND	0.001	ND	0.005	0.004	ND	0.001
Conductivity (umho/cm)	178	2125	795	310	335	246	253	312	150	352
Copper	ND	0.007	ND	ND	ND	ND	ND	0.008	ND	0.016
Cyanide	ND	ND	ND	ND	0.05	ND	0.05	0.05	ND	ND
Dissolved Oxygen	9.06	10.0	9.50	7.66	9.34	9.55	8.60	6.79	9.05	7.23
Flow Rate (mgd)	0.737	3.46	6.93	2.13	3.38	2.91	ND	ND	8.53	ND
Hardness—Total as CaCO3	51.7	520	190	77.5	108	70.8	102	120	50	135
Iron	0.806	1.44	0.596	1.40	1.61	1.19	7.32	6.77	0.952	4.52825
Lead	ND	ND	ND	ND	ND	ND	0.021	0.009	ND	0.016
Magnesium	3.33	48.6	16.8	5.98	6.12	4.55	8.02	8.25	2.98	11.3
Manganese	0.233	0.096	0.068	0.079	0.282	0.114	0.753	0.475	0.247	0.192
Nickel	ND	0.011	0.006	ND	ND	ND	0.0062	0.0104	ND	ND
Nitrate as Nitrogen	0.39	4.89	1.69	0.687	1.03	0.367	0.755	0.715	0.552	1.13
PCB-1260 (µg/L)	ND	ND	ND	ND	0.25	ND	ND	ND	ND	ND
PCB-1268 (µg/L)	ND	ND	ND	ND	0.18	ND	ND	ND	ND	ND
pH (Std Unit)	7.07	7.84	7.52	7.1	7.18	7.43	7.47	7.23	7.0625	7.09
Phosphorous	0.135	0.497	0.182	0.382	0.202	0.2	0.325	0.36	0.11	0.212
PCB, Total (µg/L)	ND	ND	ND	ND	0.43	ND	ND	ND	ND	ND
Potassium	3.59	34.7	11.3	3.13	3.12	3.67	3.43	3.4375	2.6275	3.94
Silver	ND	0.003	ND	ND	ND	ND	ND	ND	ND	ND
Sodium	14.8	226	76.0	31.6	34.0	19	9.44	9.87	9.98	14.7
Suspended Solids		21	ND	58	59	18	119	244	ND	168
Temperature (°F)	58.8	73.5	63	65.1	61.0	66.7	64.2	65.3	62.7	64.6
Trichloroethene (µg/L)	1.75	1.95	ND	ND	16.6	ND	ND	ND	ND	ND
Uranium	ND	0.009	0.002	0.010	0.01025	ND	0.001	0.001	ND	ND
Zinc	ND	ND	ND	0.024	ND	ND	ND	0.031	ND	ND

[a] The results presented in the table are the highest location averages within the area groupings.
ND = not detected
The following footnotes correspond with column titles in the above table. These are groupings of sampling locations in the area described in the title. See Figure 5.2 for sampling locations.

1 = L1 (Background)
2 = C612, C616, L291, S31, K001UP, K015UP
3 = L5, L6
4 = L10, L194
5 = L11, L12, L241
6 = C746K-5, C746KTB1A
7 = L29 (Background)
8 = L30
9 = L64 (Background)
10 = L306

Table 8.4 presents the average of maximum concentrations of selected parameters for the seep sampling location. As in Table 8.3, selected parameters are those where at least one result was above the laboratory detection limit. Results were compared to the Downstream Little Bayou results, which are in Table 8.3, since this location is downstream of the seep locations. The only parameter that was significantly different as a result of this comparison was TCE, in that it was lower than last year; however, the TCE results do not vary greatly compared to previous years' reports. For the one sampled seep, there were no detection of PCBs for a fourth consecutive year.

Additional data are presented in Section 4, Tables 4.1 through 4.21, of Volume II of this report.

Table 8.4. Selected Routine Nonradiological Surface Water Seep Sampling Surveillance Results (Average of Maximum Concentrations) for CY 2009[a]

Parameter	LBCSP5
Alkalinity (mg/L)	15.5
Calcium (mg/L)	23.4
Chloride (mg/L)	28
Conductivity (umho/cm)	340
Dissolved Oxygen (mg/L)	3.86
Magnesium (mg/L)	8.00
pH	6.32
Potassium (mg/L)	1.72
Sodium (mg/L)	34.1
Sulfate (mg/L)	17
Temperature (°F)	57.9
Trichloroethene (µg/L)	230

[a] The results presented in the table are the average values for the locations using the highest value for each location in the average calculations.

Seep sampling is representative of groundwater. Seep sampling results are compared to groundwater maximum contaminant levels for evaluation. Sample results for TCE at a surface water location downstream of the seeps at L241 showed levels less than the KPDES permitted level.

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 transported by water can adsorb either on 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 supports the bottom dwelling community of organisms. Sediments can play a significant role in aquatic ecological impacts by serving as a repository for radioactive or chemical substances that pass via bottom-feeding biota to the higher trophic levels.

Sediment Surveillance Program

Creek and ditch sediments are sampled semiannually as part of a nonradiological environmental surveillance program. Sediment samples were taken from 14 locations in CY 2009 (Figure 5.3). Sediments were sampled for the parameters listed in Table 8.5.

Table 8.5. Semiannual Nonradiological Parameters for Sediment Samples

	Parameter	
Aluminum	Lead	Vanadium
Antimony	Magnesium	Zinc
Arsenic	Manganese	PCB-1016
Barium	Mercury	PCB-1221
Beryllium	Nickel	PCB-1232
Cadmium	Potassium	PCB-1242
Calcium	Selenium	PCB-1248
Chromium	Silver	PCB-1254
Cobalt	Sodium	PCB-1260
Copper	Thallium	PCB-1268
Iron	Uranium	PCB

Sediment Surveillance Results

Table 8.6 shows the average values for locations within the area group for specific parameters. Some of the 14 locations were consolidated for reporting purposes within this document so that a more comprehensive profile could be developed for comparison purposes. These consolidation summaries are listed in the footnote section of Table 8.6.

Only the parameters that had detected results are shown. The upstream (or background) and downstream results for detected parameters are compared to identify concentrations above background. Aluminum, barium, calcium, chromium, copper, iron, magnesium, manganese, potassium, and vanadium were detected at all sites. The highest levels of metals were seen at the NSDD and Bayou Creek near the plant site.

PCBs were found in the NSDD, Bayou Creek, and Little Bayou Creek near the plant site, and downstream in Little Bayou Creek. The highest levels were downstream in Little Bayou Creek. The aroclors present were PCB-1248, PCB-1254 and PCB-1260. Additional sediment data are presented in Section 4, Tables 4.22 through 4.35, of Volume II of this report. The PCB-contaminated areas either are within the DOE-controlled area or are posted for protection of the public.

No regulatory criteria is established for any parameters for the sediment matrix; however, a comparison of the results are made to previous year's reports for trending purposes.

Soil

The major source of soil contamination is deposition from air pathways. Because DOE no longer operates any major air emission sources, routine soil surveillance is not performed; however, surface soil contamination at the Paducah Site is being addressed by the Surface Soils OU (see Environmental Restoration Program in Section 3).

Vegetation

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

Table 8.6. Selected Routine Nonradiological Sediment Surveillance Results for CY 2009[a] (Average of Maximum Concentrations)

Parameter (mg/kg)	Upstream Bayou[1]	Bayou Near Site[2]	Downstream Bayou[3]	Little Bayou Near Site[4]	Downstream Little Bayou[5]	C-746-K Area[6]	NSDD[7]	Massac Creek[8]
Aluminum	2555	3235	2490	1910	2830	1755	3360	1932
Barium	32.2	54.2	34.3	31.7	31.2	24.8	41.4	19.3
Beryllium	ND	0.667	ND	ND	ND	ND	ND	ND
Calcium	527	2756	422	997	562	631	2185	230
Chromium	7.02	13.9	6.31	25.6	31	7.48	35.1	4.38
Cobalt	3.39	5.01	3.2	3.79	2.5	ND	2.48	ND
Copper	2.7	16.6	3.46	5.26	4.7	2.87	30.2	2.3
Iron	6865	9160	4213	5715	4565	5345	4950	3250
Magnesium	285	654	267	332	262	222	506	183
Manganese	296	155	258	232	162	166	119	148
Mercury	ND	0.156	0.015	0.014	0.027	ND	0.109	ND
Nickel	ND	14.5	ND	ND	4.57	ND	17.1	ND
PCB-1248	ND	ND	ND	0.400	ND	ND	0.800	ND
PCB-1254	ND	0.220	ND	0.190	ND	ND	0.415	ND
PCB-1260	ND	0.270	ND	0.135	17	ND	0.335	ND
Polychlorinated Biphenyl	ND	0.490	ND	0.525	17	ND	1.150	ND
Potassium	162	360	130	108	269	117	307	300
Silver	ND	ND	ND	ND	ND	ND	3.05	ND
Sodium	ND	209	ND	ND	ND	ND	ND	ND
Vanadium	12	13.6	7.21	9.52	8.47	8.59	7.72	5.92
Zinc	ND	59.7	ND	38.2	28	ND	62.3	ND

[a] The results presented in the table are the highest location averages within the area groupings.
ND = not detected
The following footnotes correspond with column titles in the above table. These are groupings of sampling locations in the area described in the title. See Figure 5.3 for sampling locations.

1 = S20 (Background)
2 = C612, C616, K001, S1, S31
3 = S33
4 = S2, L194
5 = S27, S34
6 = C746KTB2
7 = S32
8 = S28 (Background)

Terrestrial Wildlife

Annual Deer Harvest

The deer population in the WKWMA is sampled annually to determine levels of radionuclides (Section 5), PCBs, and inorganic elements that might be attributable to past plant practices. There were five deer harvested in 2009 from the WKWMA.

A comparison of the metals detected in the 2009 deer with the average chemical data from background deer collected over the past 10 years shows no chemicals significantly above background.

Additional deer data are presented in Section 4, Tables 4.36 through 4.39, of Volume II, of this report.

Aquatic Life

Starting in 1987, aquatic or biological monitoring of Bayou Creek and Little Bayou Creek had been conducted following guidelines set forth in the Watershed Monitoring Program (WMP). Initially the criteria in the WMP were established by the KPDES permit. In September 2006, the KDOW issued a renewed KPDES permit for PGDP to DOE, PRS, and UDS with an effective date of November 1, 2006. It required that a revised Watershed Monitoring Plan be submitted to KDOW by December 1, 2006. Per the Watershed Monitoring Plan, toxicity monitoring was conducted, as required, by the KPDES permit; however, the benthic macroinvertebrate monitoring also was included in the Watershed Monitoring Plan though not required by the KPDES permit.

Warning signs along Bayou and Little Bayou Creek remain in order to warn members of the public about the possible risks posed by recreational contact with these waters, stream sediments, and fish caught in the creeks.

Study Area and Methods

Benthic macroinvertebrate samples were collected with a Surber square-foot bottom sampler from appropriate locations within a designated riffle at each site. Samplers selected locations within the reaches of the stream and samples were processed in a laboratory following EPA methods. Sampling locations are identified in Figure 8.1. The Modified Hilsenhoff-Biotic Index was used to evaluate the water quality of the sample locations based on the presence or absence of specific macroinvertebrates. Organisms were identified to the lowest practical taxon and counted. Instream and riparian habitat and water quality were assessed at each site following standard procedures outlined by the EPA. An analysis of the data includes general descriptive comparisons 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 are included in the analysis of the data presented in the *Watershed Monitoring Report Letter, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (PRS 2010b). Some of the metrics included are as follows:

- Total density;
- Total taxonomic richness;
- Taxonomic richness of the pollution-sensitive *Ephemeroptera, Plecoptera*, and *Trichoptera*;
- Percent community similarity index; and
- Dominants in common.

Watershed Monitoring

As previously noted, the revised Watershed Monitoring Plan reflecting changes required in the renewed KPDES permit was in place for 2009. Based on previous extensive sampling, enough historical data had been collected in order to make an informed decision in the event of an inadvertent spill or fish kill. Benthic macroinvertebrate sampling remains in the program documenting the habitat, identification and enumeration of the benthic macroinvertebrate. Toxicity sampling at the KPDES outfalls was conducted and was discussed in Section 2 of this document.

The majority of habitats for the benthic macroinvertebrates were found to be suboptimal or marginal which are the middle rankings on a four-level ranking system. The few poor rankings, bottom end of ranking system, were received for habitats were due to poor pool variability and hard surface areas, which resulted in limited root matting systems. The types of benthic macroinvertebrate identified were typical of previous years' findings.

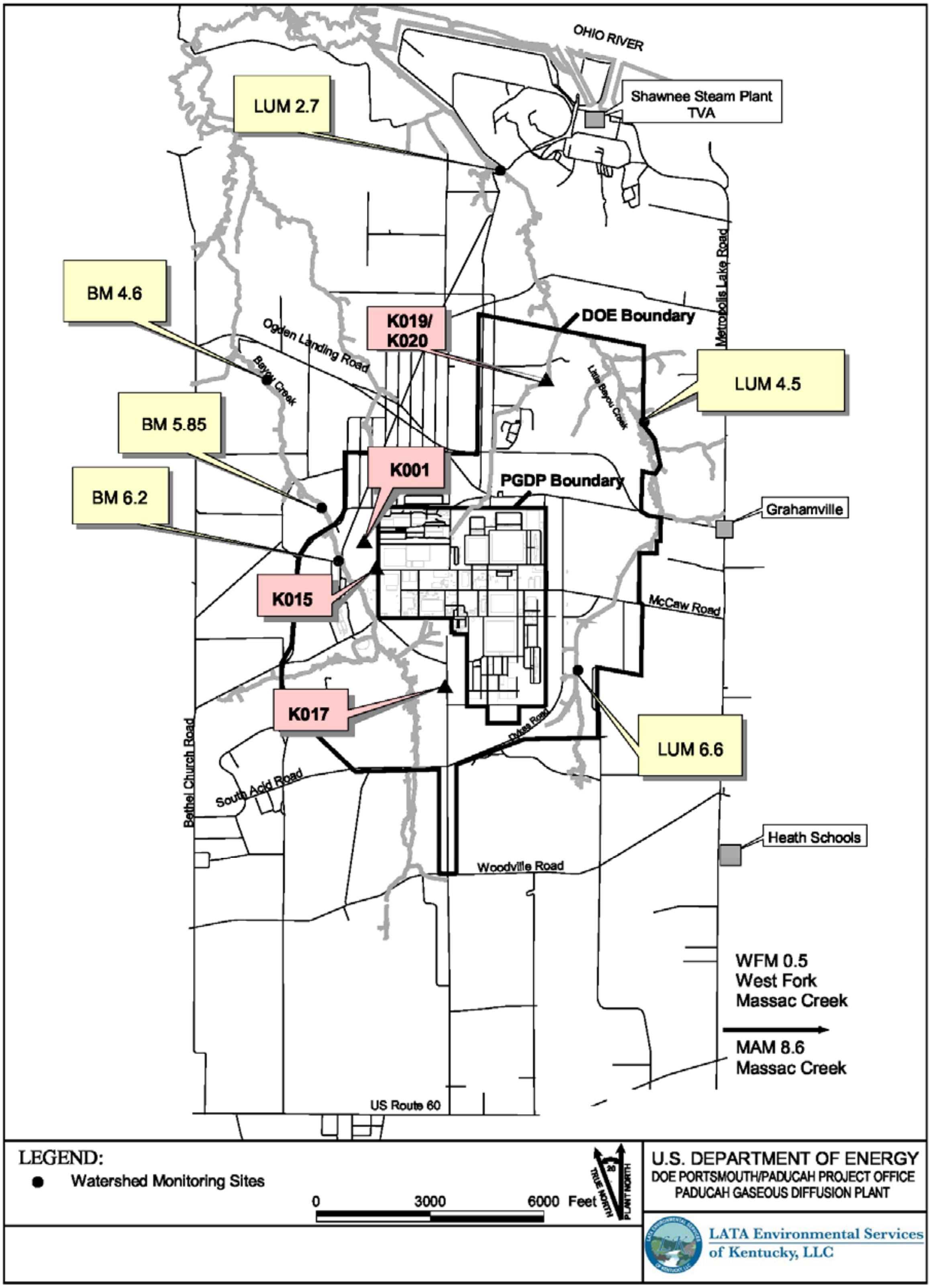

Figure 8.1. Biological Monitoring Locations

9 Groundwater Protection Program

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 and monitoring 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 TCE as a DNAPL in groundwater beneath the site.

Introduction

Monitoring and protection of groundwater resources at the Paducah Site are required by federal and Commonwealth of Kentucky regulations and by DOE Orders. Groundwater is not used for on-site purposes and when off-site contamination from the Paducah Site was discovered in 1988, DOE provided an alternate water supply to affected residences.

A CERCLA/ACO SI, completed in 1991, determined the primary off-site contaminants in the RGA to be TCE and ^{99}Tc. TCE was used until 1993 as an industrial degreasing solvent and ^{99}Tc is a fission by-product contained in nuclear power reactor returns that were brought on-site through 1976 for reenrichment of ^{235}U (DOE 2001). Such reactor returns no longer are used in the enrichment process; however, ^{99}Tc still is present in the system. Known or potential sources of TCE and ^{99}Tc include former test areas and other facilities, spills, leaks, buried waste, and leachate derived from contaminated scrap metal.

Investigations of the on-site source areas of TCE at the Paducah Site are ongoing. The main source of TCE contamination in the groundwater is near the C-400 Cleaning Building. TCE belongs to a class of contaminants called DNAPLs, which are characterized by higher density, relative to water, and low solubility. DNAPLs typically sink through the subsurface and may form pools in less permeable layers of the subsurface, as well as the base of the aquifer. This physical nature of DNAPLs makes treatment difficult because these pools constitute a continuous source of dissolved-phase contamination (i.e., plumes) deep within the aquifer. The highest concentration of DNAPL at the Paducah Site is associated with past activities at C-400.

Continued groundwater monitoring serves to detect the extent of contamination, identify the fate of the contaminants, and determine the movement of groundwater near the plant. Figure 9.1 presents the latest maps (CY 2007) of the TCE and ^{99}Tc plumes associated with PGDP.

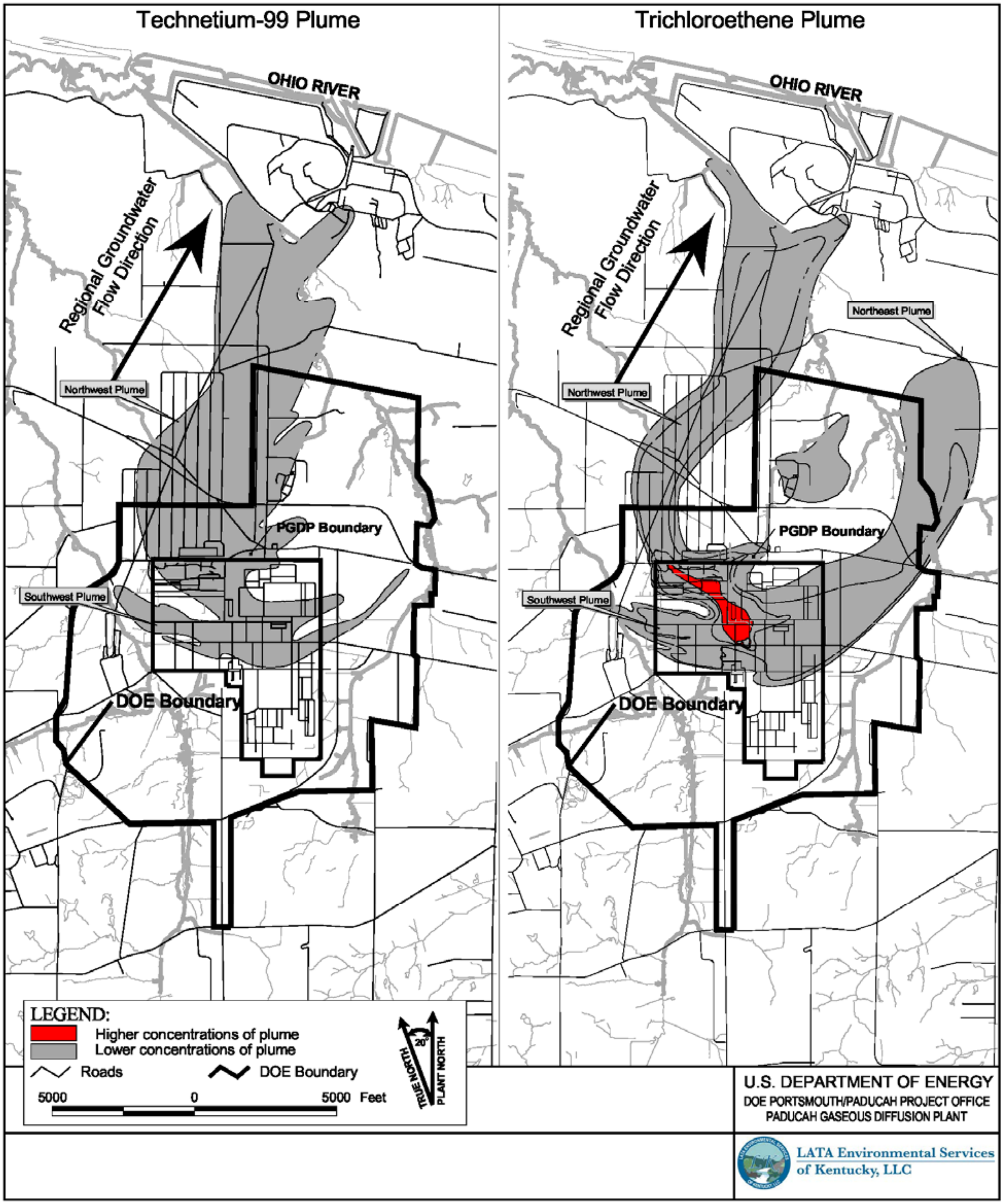

Figure 9.1. Estimated Off-Site Extent of Groundwater Plumes, 2007

Groundwater Hydrology

When rain falls to the ground, some of it flows across the surface eventually entering streams or lakes, some of it is used by plants, some evaporates and returns to the atmosphere, and some sinks into the ground. The water that sinks into the ground infiltrates the spaces between the particles of soil and rock. Groundwater is stored in and moves slowly through an aquifer. Aquifers typically consist of layers of sand and gravel or porous (sometimes fractured) rock. The speed that groundwater flows through the subsurface depends on the porosity of the soil or rock and how well the spaces are connected. Hydraulic conductivity is the physical property that describes the ease with which water can move through the pore spaces and fractures in soil, gravel, sand, and rock.

The area in the subsurface where water fills these pore spaces is called the saturated zone (Figure 9.2). The top of the saturated zone is the water table, which is the boundary between the unsaturated and saturated zones. This boundary generally gently mirrors the surface topography and is higher at natural exits such as springs, swamps, and beds of gaining streams and rivers. Groundwater can be brought to the surface naturally, either through discharge as a spring or as flow into lakes and streams, or it can be extracted through a well drilled into the aquifer. A well is a pipe/screen assembly in the ground that fills with groundwater, which then can be brought to the surface using a pump.

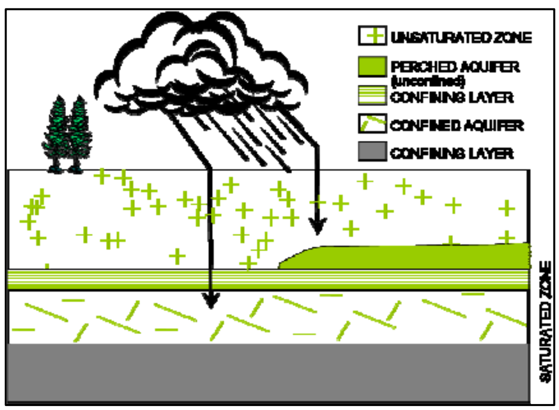

Figure 9.2. Typical Path for Rainwater Accumulation as Groundwater

Monitoring wells are used extensively at the Paducah Site to assess the effect of plant operations on groundwater quality. Wells positioned to sample groundwater flowing away from a site are called downgradient wells, and wells placed to sample groundwater flowing toward a site are called upgradient wells. Any contamination in the downgradient wells that is not present in the upgradient wells may be the result of that site.

Groundwater movement is determined by differences in the elevation of the top of the groundwater column at a specific location compared to the elevation elsewhere. This is called hydraulic head. Hydraulic head is considered to be the total energy in any water mass resulting from three components: pressure, velocity, and elevation. 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 9.3). 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.

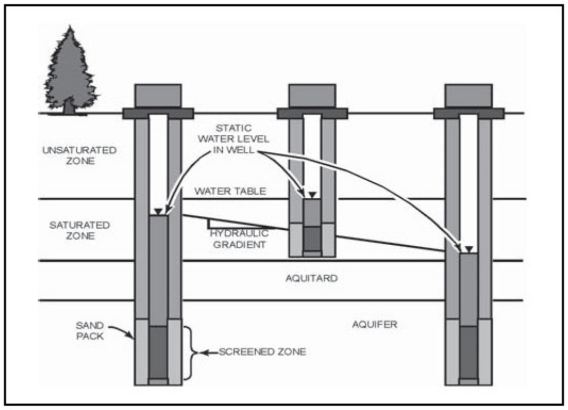

Figure 9.3. MW Construction Showing the Relationship between the Screened Zone and the Water Level in Wells Where Flow in the Aquifer Is to the Right

Only wells screened in the same zones are considered when determining the horizontal gradient. Wells screened above and below an aquitard (a geologic unit that inhibits groundwater flow) can have different hydraulic heads, thus defining a vertical gradient. If the water levels in deeper wells are lower than those in shallower wells, then the flow is through the aquitard and primarily downward.

Groundwater aquifers are one of the primary pathways by which potentially hazardous substances can spread through the environment. Substances in the soil may migrate downward due to gravity or be dissolved in rainwater, which transports them downward through the unsaturated zone into the aquifer. The contaminated water then flows laterally downgradient toward the discharge point.

Geologic and Hydrogeologic Setting

The Paducah Site, located in the Jackson Purchase region of western Kentucky, lies near the northern boundary 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.

During the Cretaceous Period, the PGDP area was a coastal marine environment. The derived sediments constitute a thick deposit of sand beneath PGDP (270 ft), with frequent lenses of silt and clay in the upper part that is called the McNairy Formation. A similar depositional environment continued into the early Paleocene Epoch. These sediments, indistinguishable in lithologic sample from the McNairy Formation, are named the Clayton Formation. (PGDP geologists commonly refer to the collective Cretaceous and lower Paleocene sediments as the McNairy Formation.)

Throughout most of the Mississippi Embayment and extending to under the south side of the PGDP, the Paleocene Porters Creek Clay overlies the McNairy/Clayton Formation. Locally, the Porters Creek Clay consists predominately of silt with sand and clay interbeds that were deposited in marine and brackish water environments. Much later erosion, associated with formation of the ancestral Tennessee River basin, thinned the Porters Creek Clay to the north and completely removed it under most of the PGDP and adjacent area to the north. The McNairy and Clayton Formations and the Porters Creek Clay uniformly dip 30 to 35 ft per mile (5.7 to 6.6 m per km) to the south-southwest.

Pliocene-Pleistocene (the geologic age of these formations is uncertain) gravels (and lesser sands), representing a broad alluvial fan deposit that extended across all of the Jackson Purchase region at one time, overlie the Porters Creek Clay to the south. These gravels constitute the oldest member of the lower continental deposits. The ancestral Tennessee River cut through the PGDP area (close to the present course of the Ohio River) later in the Pleistocene, eroding through the Porters Creek Clay to form a wide valley. A subcrop of the Porters Creek Clay, buried in the sediments beneath the PGDP, marks the south side of the ancestral Tennessee River valley. Braided river deposits of sand and gravel, commonly 30-ft (9.1-m) thick, fill the lower portion of the ancestral Tennessee River valley. These sands and gravels form the youngest member of the lower continental deposits.

As sediments from retreating Pleistocene glaciers plugged tributaries to the Mississippi River, lakes formed in the ancestral Tennessee River valley. These lake deposits predominately consisted of silt. Intervals of common sand and gravel lenses within the silt beneath PGDP attest to minor periods of active erosion of the Pliocene-Pleistocene (the geologic age of these formations is uncertain) gravels to the south and redeposition within the valley. (The thick silt interval, with interbedded sand and gravel member, is collectively called the upper continental deposits). Finally, layers of loess, wind-blown silt derived from the receding glaciers, blanketed the entire Jackson Purchase region. The combined thickness of upper continental deposits and loess at PGDP is commonly 60 ft (18.3 m) thick.

The local groundwater flow systems at the Paducah Site include the following (from shallowest to deepest): (1) the Terrace Gravel flow system, (2) UCRS, (3) RGA, and (4) the McNairy flow system. The Terrace Gravel consists of shallow Pliocene-Pleistocene (the geologic age of these formations is uncertain) gravel deposits in the southern portion of the Paducah Site. These deposits usually lack sufficient thickness and saturation to constitute an aquifer, but are a locally important source of groundwater recharge to the RGA.

The UCRS consists of the silts, with sand and gravel interbeds, of the upper continental deposits and overlying loess. Groundwater flow within the UCRS is predominately downward and is the primary recharge to the RGA. The RGA is the uppermost aquifer at the Paducah Site and was used formerly as a drinking water source by private residences north of the site. It consists primarily of the Lower Continental Deposits, a thick unit of sand and gravel formed by the ancestral Tennessee River, and includes contiguous sands and gravels of the Upper Continental Deposits, the McNairy Formation, and alluvium of the Ohio River. The Ohio River is the regional discharge/drainage feature for the area hydrologic system. Flow in the RGA and McNairy is northward to discharge into the Ohio River.

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. Two communities, Grahamville and Heath, lie within 2 miles (3.2 km) east of the plant.

Historically, groundwater was the primary source of drinking water for residents and industries in the vicinity of the plant area. Some area residents and industries have chosen to replace groundwater sources with water supplied by the West McCracken County Water District. In areas where the groundwater is either known to be contaminated or is suspected of becoming contaminated in the future, the Paducah Site continues to provide municipal water. Several residential out-of-service wells are utilized by DOE for monitoring (per written agreements). Residential wells that no longer are sampled have been capped and locked.

PGDP uses surface water from the Ohio River for process waters and on-site drinking water. The nearest community downstream of Paducah using surface water for drinking water is Cairo, IL, which is located at the confluence of the Upper Mississippi and Ohio Rivers.

Groundwater Monitoring Program

The primary objectives of groundwater monitoring at the Paducah Site are early detection of any contamination resulting from past and/or present land disposal of wastes and provision of data, which can be used for decision documents, if contamination is detected. Additional objectives outlined in DOE Order 450.1A, *Environmental Protection Program*, require implementation of a sitewide approach for groundwater monitoring.

The sitewide approach is outlined in the following three documents related to groundwater monitoring: (1) Groundwater Protection Plan, (PRS 2007); (2) Groundwater Protection Plan (BJC 2004); and (3) and the Paducah Site EMP (PRS 2009a; PRS 2009b). Approximately 170 monitoring wells (MWs) and residential wells are sampled in accordance with DOE orders and federal, Commonwealth of Kentucky, and local requirements. Well sampling is included in several different monitoring programs, which are described as follows. In 2009, an additional 63 MWs were installed to supply additional groundwater characterization data as the ER Program moves forward with addressing groundwater contamination as part of the GWOU future response actions.

Resource Conservation and Recovery Act Permit Monitoring Programs

The only hazardous waste facility at the Paducah Site that requires groundwater monitoring is the C-404 Landfill (Figure 9.4). The C-404 Low-Level Radioactive Waste Burial Ground was used for the disposal of uranium-contaminated solid wastes until 1986 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 cap and was certified “closed” as a hazardous waste landfill in 1987.

The landfill now is monitored under post-closure monitoring requirements. According to the Kentucky C-404 Post-Closure Permit, 15 wells (MWs 84–95, 226, 227, and 420) monitor groundwater quality. Four of the 15 wells monitor the UCRS, while 11 of the wells monitor the underlying RGA. The sampling results also are examined with respect to the gradient of the well. Seven of the 15 wells are considered upgradient to the landfill while the remaining eight wells are downgradient to the landfill. All sampling events were conducted on a semiannual basis per the Permit.

During 2009, MWs at the C-404 Landfill were sampled and analyzed for total and dissolved chromium, arsenic, cadmium, lead, mercury, selenium, and uranium. Also monitored are TCE, ^{99}Tc and the activity concentrations of the uranium radionuclides. Field parameters (i.e., temperature, pH, depth to water, etc.) are also collected at the C-404 Landfill MW locations. TCE exceeded the regulatory maximum contaminant level (MCL) in all upgradient wells and in all downgradient wells. The extent of the contamination is likely related to the northwest and southwest TCE plume and not C-404 itself. Remediation of the TCE plume will take place as a CERCLA action under the GWOU. Chromium exceeded the regulatory MCL in one upgradient well and one downgradient well. Tc-99 exceeded its regulatory value at one downgradient well. Results are reported to KDWM semiannually. Regulatory MCL exceedances are reported to KDWM in semiannual reports as directed by the permit. A summary of the detected maximum results for each of the wells is provided in Table 9.1. Parameters with no detections are not listed.

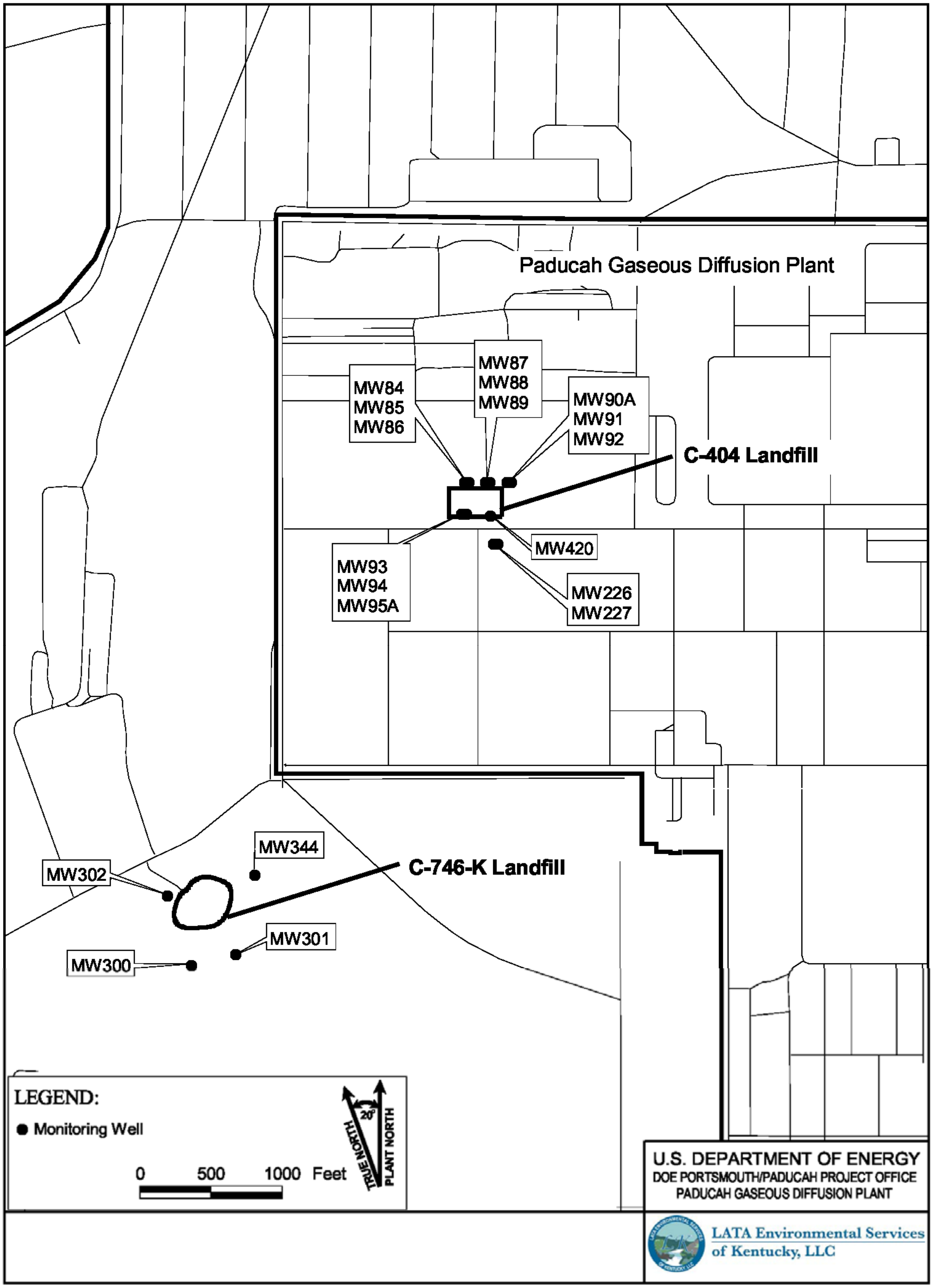

Figure 9.4. MW Locations near the C-404 and C-746-K Landfills

Table 9.1. Summary of Maximum Groundwater Results from the RGA at C-404 Landfill for CY 2009[a]

			Upgradient Wells						Downgradient Wells								
			RGA					UCRS	RGA					UCRS			
Chemical Name	**Units**	**MW 226**	**MW 227**	**MW 420**	**MW 93**	**MW 95A**	**MW 94**	**MW 84**	**MW 86**	**MW 87**	**MW 89**	**MW 90A**	**MW 92**	**MW 85**	**MW 88**	**MW 91**	**Reference Value**
1,1-Dichloroethene	ug/L	26	4.2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Arsenic	mg/L	ND	ND	0.001	0.003	ND	ND	0.002	ND	0.001	ND	ND	ND	0.014	0.003	0.003	0.05
Arsenic, Dissolved	mg/L	ND	ND	ND	0.001	ND	0.001	0.002	ND	ND	ND	ND	ND	0.013	0.003	0.001	--
Barometric Pressure	Inc/Hg	30.5	30.6	30.2	30.5	30.1	30.5	30.4	30.5	30.4	30.5	30.1	30.5	30.4	30.5	30.5	--
Beta activity	pCi/L	49.2	7.61	ND	ND	3.9	ND	ND	ND	ND	5.68	ND	5.5	ND	ND	ND	--
Carbon tetrachloride	ug/L	8.6	1.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	--
Chromium	mg/L	ND	ND	ND	ND	ND	**0.144**	ND	ND	ND	ND	ND	ND	ND	ND	**1.03**	0.05
Chromium, Dissolved	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.011	--
cis-1,2-Dichloroethene	ug/L	13	2	ND	ND	33	ND	ND	64	ND	1.6	ND	ND	ND	ND	ND	--
Iron	mg/L	ND	ND	0.155	2.84	ND	11.2	3.78	ND	0.545	ND	0.243	ND	1.68	7.61	17	--
Lead	mg/L	ND	ND	ND	0.001	ND	0.005	0.002	ND	ND	ND	ND	ND	0.001	0.005	0.009	0.05
Lead, Dissolved	mg/L	ND	ND	ND	ND	ND	0.003	ND	ND	ND	ND	ND	ND	ND	0.003	NS	--
Manganese	mg/L	ND	ND	0.095	0.26	ND	0.13	0.594	ND	0.061	ND	0.082	ND	0.011	0.086	0.086	--
Selenium	mg/L	ND	ND	ND	ND	ND	0.008	ND	ND	ND	ND	ND	ND	ND	ND	0.013	0.01
Selenium, Dissolved	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.007	--
Sulfate	mg/L	ND	ND	7.3	7.8	ND	140	7.9	ND	9	ND	7.5	ND	12	120	9.1	--
Technetium-99	pCi/L	92.3	16.5	31.2	ND	18.6	338	ND	ND	ND	ND	ND	ND	172	48.3	**3030**	900
Total Organic Carbon	mg/L	ND	ND	ND	ND	ND	3.9	ND	ND	ND	ND	ND	ND	ND	2.3	1.1	--
Trichloroethene	ug/L	**880**	**210**	**330**	**960**	**620**	**12**	**850**	**820**	**230**	**29**	**7.6**	**13**	**100**	**110**	**85**	5
Turbidity	NTU	119	99.6	4.5	50.5	10.2	162	86.5	221	10.4	269	4.7	71.2	139	309	946	--
Uranium	mg/L	ND	ND	ND	ND	ND	0.004	ND	ND	ND	0.001	ND	ND	0.001	0.002	0.001	--
Uranium, Dissolved	mg/L	ND	ND	ND	ND	ND	0.003	ND	ND	ND	ND	ND	ND	0.001	ND	NS	--
Uranium-234	pCi/L	ND	ND	ND	0.591	ND	2.7	1.56	ND	ND	ND	ND	ND	ND	0.733	ND	--
Uranium-235	pCi/L	ND	ND	ND	ND	ND	0.162	ND	ND	ND	ND	ND	ND	ND	0.081	ND	--
Uranium-238	pCi/L	ND	ND	ND	0.364	ND	1.59	0.777	ND	0.16	ND	ND	ND	0.474	0.78	ND	--

[a] MCLs for 404 are from 40 CFR 264.94 except for TCE and Tc-99.
ND = not detected -- = no reference value for this parameter **Bold = exceeds criteria** NS = not sampled

Solid Waste Landfill Groundwater Monitoring Programs

Post-closure groundwater monitoring continues for the C-746-S Residential Landfill. The landfill stopped receiving solid waste by 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. No monitoring is done on the C-746-T Landfill because it had fulfilled the two years of post-closure environmental monitoring and maintenance requirements that were required as part of its closure.

The groundwater monitoring system for C-746-S&T consists of upgradient, sidegradient, and downgradient wells (Figure 9.5). The monitoring system is designed to monitor the UCRS, the upper portion of the RGA (URGA), and lower portion of the RGA (LRGA).

The MWs at C-746-S&T are sampled quarterly and in accordance with 401 *KAR* 48:300. The analytes are dictated by a KDWM-approved solid waste landfill permit modification.

During 2009, beta activity exceeded regulatory MCLs in all three well systems (LRGA, URGA and UCRS); however, no regulatory exceedances occurred in upgradient wells. TCE concentrations exceeded regulatory MCLs in some LRGA and URGA wells (upgradient and downgradient wells). The KDWM was notified of the exceedances. In addition, results were reported to KDWM on a quarterly basis. A summary of the maximum results of the LRGA, URGA and UCRS wells monitored by gradient is provided in Table 9.2.

The C-746-U Contained Landfill, a solid waste landfill at the Paducah Site, was completed in 1996 and operation was initiated in 1997. Solid waste regulations require groundwater monitoring of the landfill. Monitoring wells were installed in clusters of three. The three well clusters had wells in the UCRS, URGA, and LRGA (Figure 9.5) and are additionally monitored by gradient (upgradient, sidegradient, and downgradient).

During 2009, beta activity exceeded regulatory MCLs in LRGA and URGA wells. PCBs were detected in downgradient UCRS wells. TCE concentrations exceeded regulatory MCLs in upgradient and downgradient LRGA and URGA and downgradient UCRS wells. The KDWM was notified of the exceedances. In addition, results were reported to KDWM on a quarterly basis as specified by the permit. A summary of the maximum results of the LRGA, URGA and UCRS wells monitored by gradient is provided in Table 9.3.

Based on groundwater data obtained from sampling events conducted in 2006 at the C-746-U Landfill, a groundwater assessment plan was required by the permit due to data exceedances. In February 2007, DOE submitted a final assessment plan to the regulatory agency. This plan described the planned methods to assess the contaminants and provide a process of planned steps to perform groundwater evaluations. This plan was implemented in 2008 and a final report was provided to KDWM in 2009 containing a summary of the results of the activities conducted under the approved groundwater assessment plan.

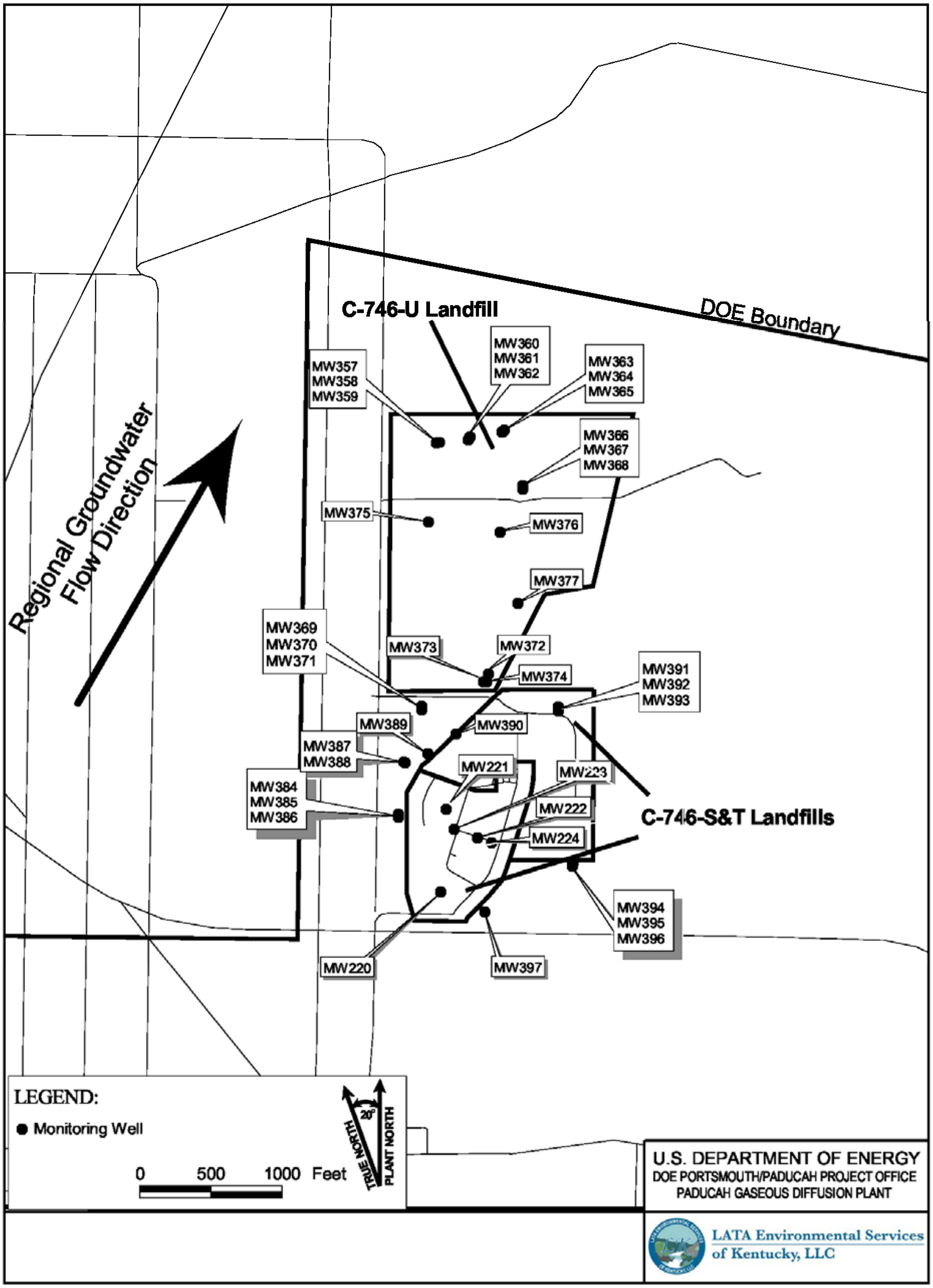

Figure 9.5. MW Locations near the C-746-S&T and C-746-U Landfills

Table 9.2. Summary of Maximum Groundwater Results at C-746-S&T Landfills for CY 2009[a]

		Lower RGA			Upper RGA			UCRS Wells				
	Parameter	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Reference**	**Value**
ANION (mg/L)	Bromide	ND	ND	ND	ND	ND	ND	ND	2.1	ND	--	
	Chloride	49	33	47	49	54	50	18	170	93	--	
	Fluoride	0.28	0.3	0.16	0.95	0.24	0.23	0.17	0.62	0.55	KYREG	4
	Nitrate as Nitrogen	1.4	1	1.8	1.9	1.3	1.6	ND	2.8	ND	KYREG	10
	Sulfate	25	19	14	38	24	17	8	51	23	--	
METAL (mg/L)	Aluminum	ND	ND	0.385	1.12	ND	ND	ND	11.7	0.328	--	
	Arsenic	0.003	0.002	0.002	0.004	0.003	0.002	0.003	0.003	0.003	KYREG	0.05
	Barium	0.253	0.233	0.255	0.363	0.208	0.251	0.106	0.418	0.429	KYREG	2
	Calcium	28.2	28.7	28.2	37.9	26.9	27.7	11.3	49.9	42.4	--	
	Chromium	ND	ND	ND	**0.137**	ND	ND	ND	ND	ND	KYREG	0.1
	Cobalt	ND	ND	ND	0.006	ND	ND	ND	0.013	0.0019	--	
	Iron	1.91	ND	0.85	0.987	0.212	0.563	3.33	6.29	4.38	--	
	Lead	ND	ND	ND	ND	ND	ND	ND	0.003	ND	KYREG	0.05
	Magnesium	11.9	9.45	11.3	15.2	10.6	11.3	3.29	20.2	17.7	--	
	Manganese	0.399	0.005	0.012	0.158	0.015	0.009	0.036	2.33	0.534	--	
	Molybdenum	ND	ND	ND	0.0107	ND	0.002	ND	0.0103	ND	--	
	Nickel	ND	ND	ND	0.295	ND	0.042	ND	ND	ND	--	
	Potassium	1.88	1.64	1.95	5.5	1.46	10.5	0.44	1.83	1.03	--	
	Selenium	0.008	0.006	0.009	0.011	0.011	0.008	ND	0.020	0.013	KYREG	0.05
	Sodium	44.6	42.1	35.7	62	48	42.6	83.9	126	117	--	
METAL-D (mg/L)	Barium, Dissolved	0.238	0.232	0.254	0.375	0.21	0.261	0.105	0.385	0.425	--	
	Chromium, Dissolved	ND	ND	ND	0.0139	ND	ND	ND	ND	ND	--	
METEO	Barometric Pressure (in/Hg)	30.7	30.1	30.1	30.5	30.1	30.1	30.8	30.3	30.1	--	
PHYSC	Depth to Water (ft)	44.0	43.2	64.4	72.9	42.8	58.9	27.9	38.4	9.67	--	
	Dissolved Oxygen (mg/L)	5.26	2.22	5.81	5.74	2.39	6.2	1.11	7.54	0.68	--	
	Dissolved Solids (mg/L)	249	224	219	310	254	237	377	537	492	--	

Table 9.2. Summary of Maximum Groundwater Results at C-746-S&T Landfills for CY 2009[a] (Continued)

		Lower RGA			Upper RGA			UCRS Wells				
	Parameter	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Reference**	**Value**
	pH (Std Unit)	6.37	6.91	6.14	6.31	6.16	6.29	6.32	6.74	6.57	--	
	Redox (mV)	440	373	399	606	226	594	200	525	135	--	
	Temperature (°F)	64.5	64.2	63.7	72.6	64.1	71.5	65.9	65.1	63.5		
RADS	Alpha activity	6.84	6.92	ND	ND	6.9	ND	ND	8.09	ND	KYREG	15
(pCi/L)	Beta activity	**56.8**	**132**	14.9	**167**	**183**	26.8	ND	**52.3**	6.41	KYREG	50
	Technetium-99	75.4	148	19.8	202	219	28	18.3	82.1	21.4	TTL	900
VOA	1,2,3-Trichloropropane	ND	ND	ND	ND	ND	ND	ND	29	ND	--	
(µg/L)	*Cis*-1,2-Dichloroethene	1.2	ND	ND	1.2	ND	ND	ND	ND	ND	--	
	Trichloroethene	**17**	1.3	4.9	**19**	4.5	**12**	1.3	2.2	1.9	KYREG	5
WETCHEM	Chemical Oxygen Demand (mg/L)	57	ND	ND	ND	ND	ND	ND	70	27	--	
	Conductivity (umho/cm)	440	547	374	549	524	394	428	956	865	--	
	Total Organic Carbon (mg/L)	2.4	ND	ND	1.1	1.6	ND	3.6	26	8.1	--	
	Total Organic Halides (µg/L)	83.1	29.6	27.5	35.8	25.6	35.5	63.9	441	227	--	
	Turbidity (NTU)	10.9	25.2	34.2	111	18.5	22.1	43.6	350	16.9	--	

[a] MCLs are from 401 *KAR* 47:030, except for Tc-99.
KYREG = Kentucky regulations
MCL = maximum contaminant level
ND = not detected
PHYSC = physical parameters
TTL = target treatment level for Northwest Plume
VOA = volatile organic analyte
WETCHEM = wet chemistry parameters
Bold = exceeds criteria
-- = no reference value for this parameter

Table 9.3. Summary of Maximum Groundwater Results at C-746-U Landfill for CY 2009[a]

		Lower RGA			Upper RGA			UCRS Wells			
	Parameter	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Up-gradient**	**Reference**	**Value**
(mg/L)	Chloride	33	39	48	32	42	49	13	100	--	
	Fluoride	0.2	0.17	0.18	0.27	0.31	0.23	0.33	0.32	KYREG	4
	Nitrate as N	ND	ND	1.5	3.6	ND	ND	1.4	1.5	KYREG	10
	Sulfate	110	32	220	74	31	150	77	9.1	--	
METAL (mg/L)	Aluminum	ND	ND	ND	0.516	ND	0.403	11.2	0.65	--	
	Arsenic	0.001	0.004	0.002	0.001	0.001	0.002	0.003	0.002	KYREG	0.05
	Barium	0.113	0.207	0.204	0.202	0.205	0.422	0.159	0.179	KYREG	2
	Boron	0.282	ND	1.44	0.331	ND	0.901	ND	ND	--	
	Calcium	39.4	28.7	71.8	30.6	25.4	57.1	27	26.1	--	
	Cobalt	0.006	0.008	ND	0.011	0.001	0.044	0.013	ND	--	
	Iron	1.62	13.9	0.308	3.5	0.892	4.94	5.11	0.486		
	Lead	ND	ND	ND	0.007	ND	ND	0.003	ND	KYREG	0.05
	Magnesium	16.6	11.3	29.1	12.9	10.7	23	11.9	10.7	--	
	Manganese	0.412	1.94	0.111	0.939	0.32	0.466	0.986	0.017	--	
	Molybdenum	ND	ND	ND	ND	ND	ND	0.002	ND	--	
	Nickel	ND	ND	ND	ND	ND	0.009	0.006	ND	--	
	Potassium	2.49	2.79	3.04	1.84	1.85	2.34	0.964	0.514	--	
	Selenium	0.006	0.005	0.008	0.005	0.007	0.007	ND	0.029	KYREG	0.05
	Sodium	44.7	34.9	64.8	71.3	75.4	62.4	149	134	--	
	Uranium	ND	ND	ND	ND	ND	ND	0.011	0.001	KYREG	0.03
METAL-D (mg/L)	Barium, Dissolved	0.11	0.202	0.213	0.217	0.207	0.445	0.165	0.176	--	
	Uranium, Dissolved	ND	ND	ND	ND	ND	ND	0.0114	0.00159	--	
METEO	Barometric Pressure (in/HG)	30.74	30.47	30.95	30.24	30.92	30.89	30.95	30.89	--	
PHYSC	Depth to Water (ft)	48.01	48.2	43.11	47.84	47.78	41.77	43.74	29.29	--	
	Dissolved Oxygen (mg/L)	3.25	3.38	3.61	3.24	2.61	1.69	5.25	6.57	--	
	Dissolved Solids (mg/L)	333	247	555	272	294	452	484	443	--	
	pH (Std Unit)	6.26	6.29	6.18	6.35	6.56	6.28	6.82	6.88	--	
	Redox (mV)	408	134	437	520	349	362	489	484	--	
	Temperature ^{o}F	66.7	66	64.5	70.4	67.2	67.9	68.1	70.4	--	
Pesticide/ PCB (µg/L)	PCB-1016	ND	ND	ND	0.38	ND	0.42	0.88	ND	--	
	PCBs	ND	ND	ND	0.38	ND	0.42	**0.88**	ND	MCL	0.5
RADS (pCi/L)	Alpha activity	4.13	ND	4.97	ND	ND	10.1	**15.3**	ND	KYREG	15
	Beta activity	**57.6**	**62.8**	38.8	39.2	**58.6**	**72.2**	7.48	6.95	KYREG	50
	Radium-226	ND	1	ND	1.09	ND	1.11	ND	0.701	KYREG	5
	Technetium-99	52.8	32.2	43.4	44.5	80.4	77.6	ND	19.6	TTL	900
VOA (µg/L)	Trichloroethene	**13**	4.2	**22**	**6.6**	4.8	**18**	**12**	4.1	KYREG	5
WETCHEM	Conductivity (umho/cm)	557	438	904	475	454	758	783	781	--	
	Suspended Solids (mg/L)	ND	ND	ND	ND	ND	ND	20	ND	--	

Table 9.3. Summary of Maximum Groundwater Results at C-746-U Landfill for CY 2009 (Continued)

		Lower RGA			Upper RGA			UCRS Wells			
	Parameter	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Side-gradient**	**Up-gradient**	**Down-gradient**	**Up-gradient**	**Reference**	**Value**
	Total Organic Carbon (mg/L)	ND	ND	ND	1.9	3.6	2.2	3.9	1.9	--	
	Total Organic Halides (µg/L)	18.9	21.1	30.3	23.9	103	56	44.5	78	--	
	Turbidity (NTU)	264	37.2	52.9	259	14	22.8	106	25.8	--	

[a] MCLs are from 401 *KAR* 47:030, except for Tc-99.
KYREG = Kentucky regulations
MCL = maximum contaminant level
ND = not detected
PHYSC = physical parameters
TTL = target treatment level for Northwest Plume
VOA = volatile organic analyte
WETCHEM = wet chemistry parameters
Bold = exceeds criteria
-- = no reference value for this parameter

C-746-K Sanitary Landfill Groundwater Monitoring

The C-746-K Sanitary Landfill was used at the PGDP between 1951 and 1981 primarily for the disposal of fly ash. Postclosure groundwater monitoring continues for the C-746-K Landfill on a quarterly basis and these results are summarized in Table 9.4. Regulatory MCL exceedances of reference values were found for beta activity, 1,1-dichloroethene, *cis*-1,2-dichloroethene, TCE, and vinyl chloride. The UCRS and RGA are not present at the C-746-K site. Wells at the landfill are installed to monitor groundwater in the Terrace Gravel (Figure 9.4).

Table 9.4. Summary of Maximum Groundwater Results at C-746-K Landfill for CY 2009

	Parameter	**MW300**	**MW301**	**MW302**	**MW344**	**Reference**	**Value**
ANION (mg/L)	Chloride	15	83	9.5	22	--	
	Ferrous	96	220	ND	ND	--	
	Sulfate	1070	1910	150	150	--	
METAL (mg/L)	Aluminum	ND	ND	0.493	4	--	
	Arsenic	0.002	ND	ND	0.004	KYREG	0.05
	Barium	0.02	0.024	0.057	0.067	KYREG	2
	Calcium	297	638	49.3	55.8	--	
	Iron	104	228	0.425	3.56	--	
	Lead	ND	ND	0.021	0.005	KYREG	0.05
	Magnesium	59.4	134	26.9	18.3	--	
	Manganese	27.4	15.9	0.433	0.299	--	
	Nickel	0.042	0.011	0.005	0.005	--	
	Potassium	20.8	45.9	0.351	1.71	--	
	Sodium	21.2	96.7	78.6	29.9	--	
	Uranium	ND	0.002	ND	ND	KYREG	0.03
METAL-D (mg/L)	Arsenic, Dissolved	0.002	0.002	ND	0.003	KYREG	0.05
	Barium, Dissolved	0.022	0.02	0.0601	0.057	KYREG	2
	Uranium, Dissolved	ND	0.004	ND	ND	KYREG	0.03
METEO (in/HG)	Barometric Pressure	30.1	30.1	30.1	30.1	--	

Table 9.4. Summary of Maximum Groundwater Results at C-746-K Landfill for CY 2009 (Continued)

	Parameter	MW300	MW301	MW302	MW344	Reference	Value
PHYSC	Depth to Water (Ft)	4.9	8.15	8.7	23.2	--	
	Dissolved Oxygen (mg/l)	88	1.43	1.89	1.23	--	
	pH (Std Unit	5.21	6	6.12	6.13	--	
	Redox (mV)	364	209	448	344	--	
	Temperature (^oF)	67.1	65.3	67.1	62.1	--	
RADS (pCi/L)	Beta Activity	37	**85**	ND	5.57	KYREG	50
VOA (µg/L)	1,1-Dichloroethane	52	4.8	ND	ND	--	
	1,1-Dichloroethene	**93**	5.5	ND	ND	KYREG	7
	cis-1,2-Dichloroethene	**640**	68	ND	ND	MCL	70
	Trichloroethene	**14**	3.8	2.1	1.3	KYREG	5
	Vinyl chloride	**120**	**7.9**	ND	ND	KYREG	2
WETCHEM	Alkalinity (mg/L)	90	404	234	99	--	
	Conductivity (umho/cm)	1650	3360	1650	574	--	
	Turbidity (NTU)	135	82.2	135	61.7	--	

KYREG = Kentucky regulations (for reference only)
ND = not detected
VOA = volatile organic analyte
Bold = exceeds criteria
-- = No reference value for this parameter

Residential (Federal Facility Agreement) Monitoring

DOE conducts sampling of 17 residential wells potentially affected by the contaminant plume. Residents are protected under the DOE Water Policy in that the residents are provided a municipal water source. During 2009, 15 of the wells were monitored annually and two wells were sampled on a monthly basis. All residential wells were analyzed for TCE and ^{99}Tc. Additionally, the wells that were monitored monthly were sampled for alpha and beta activity. Field parameters (e.g., depth to water, pH) also were collected for all samples; however, only the TCE and ^{99}Tc are addressed in this data evaluation of the ASER.

As stated previously, the hydrologic unit in which residential wells are screened is uncertain; however, most are believed to be RGA wells. Out of the 15 wells that are sampled annually, TCE was detected in one well, R2. No ^{99}Tc was detected in the 15 wells. TCE was detected in both wells that are sampled monthly, R294 and R302; however, ^{99}Tc, a beta emitter, was not detected in either of these two wells. A summary of the detected concentrations is reflected in Table 9.5. The residential water results are collected from residential wells that are not operated for consumption.

For one residential well, R424, DOE has provided the residents with a carbon filter treatment system to allow them to have safe drinking water. These filters are replaced semiannually, and the groundwater is sampled before and after filter replacement. Before treatment, the groundwater in the well contains TCE above levels established by the EPA Safe Drinking Water Act (SDWA); however, after treatment, the concentrations are below those levels. The location of the well relative to PGDP makes it highly improbable that the contaminants migrated from the Paducah Site. Based upon this rationale, the results from this residential well were not included in the summary presented in Table 9.5.

Table 9.5. Summary of Maximum Groundwater Results from Residential Monitoring for CY 2009

Well Number	^{99}Tc, pCi/L	TCE, µg/L	Type monitoring
R2	ND	**31**	annually
R294	ND	4.8	monthly
R302	ND	**15**	monthly
	MCL=NA	MCL = 5	

MCL = maximum contaminant level (for reference only)
ND = not detected
NR = not reported
Bold = exceeds criteria

Environmental Surveillance Monitoring

Environmental surveillance monitoring is defined as perimeter-exit-pathway (off-site exposure) 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 Site EMP (PRS 2009a; PRS 2009b).

During 2009, surveillance wells located on and off DOE property were sampled for volatiles, total and dissolved metals, radionuclides, and anions. Additionally, wet chemistry and field parameters were analyzed. Table 9.6 provides a summary of the maximum detected results for each hydrogeologic unit sampled for the surveillance program. From the routine well monitoring program in the RGA, several parameters were reported as exceeding the regulatory MCLs including the following: anions (nitrate); metals (chromium, and uranium); radionuclides (alpha and beta activity, uranium, and ^{99}Tc); and volatiles (including 1,1-dichloroethene, carbon tetrachloride, TCE, and vinyl chloride). The maximum TCE value reported (from routine monitoring program wells) in the RGA is 77,000 µg/L. TCE also was detected in the McNairy at 49 µg/L, and the UCRS at 20,000 µg/L. These values exceed the regulatory MCL value of 5 µg/L. During 2009, the maximum ^{99}Tc value reported (from routine monitoring program wells) in the RGA was 16,900 pCi/L. The contamination in the RGA is being addressed by CERCLA actions for the GWOU; Section 3.

Monitoring Well Rehabilitation

In 2009 a revised MW maintenance plan was approved by KDWM and implemented for 45 MWs. Well rehabilitation removes accumulated biofilm and blocking materials contained within the well and surrounding aquifer using equipment that goes into the well and uses surging techniques. Well pumping equipment is removed and cleaned and reinstalled into the well after rehabilitation activities are completed.

Table 9.6. Summary of Maximum Groundwater Results from Environmental Surveillance Monitoring for CY 2009

	Parameter	Eocene	McNairy	RGA	Rubble Zone	UCRS	Reference	Value
ANION (mg/L)	Chloride	NA	NA	110	NA	45	--	
	Ferrous	NA	NA	6.8	NA	ND	--	
	Fluoride	NA	NA	0.25	NA	0.25	MCL	4
	Nitrate as Nitrogen	NA	NA	**22**	NA	5.2	MCL	10
	Sulfate	NA	NA	94	NA	100	--	
METAL (mg/L)	Aluminum	NA	NA	3.02	NA	0.554	--	
	Arsenic	NA	NA	0.004	NA	0.001	MCL	0.05
	Barium	NA	NA	0.342	NA	0.29	MCL	2

Table 9.6. Summary of Maximum Groundwater Results from Environmental Surveillance Monitoring for CY 2009 (Continued)

	Parameter	Eocene	McNairy	RGA	Rubble Zone	UCRS	Reference	Value
	Calcium	NA	NA	44.7	NA	34.4	--	
	Chromium	NA	NA	**0.787**	NA	**0.339**	MCL	0.1
	Cobalt	NA	NA	0.006	NA	0.003	--	
	Copper	NA	NA	0.068	NA	ND	--	
	Iron	NA	NA	11.6	NA	3.04	--	
	Lead	NA	NA	0.002	NA	ND	MCL	0.05
	Magnesium	NA	NA	17.9	NA	13.4	--	
	Manganese	NA	NA	0.423	NA	0.079	--	
	Molybdenum	NA	NA	0.030	NA	0.005	--	
	Nickel	NA	NA	0.152	NA	0.127	--	
	Potassium	NA	NA	7.14	NA	2.85	--	
	Selenium	NA	NA	0.007	NA	0.005	MCL	0.05
	Sodium	NA	NA	68.7	NA	59.2	--	
	Uranium	ND	ND	0.011	NA	**0.059**	MCL	0.02
METAL-D (mg/L)	Arsenic, Dissolved	ND	ND	0.003	ND	ND	--	
	Barium, Dissolved	ND	ND	0.31	ND	0.273	--	
	Calcium, Dissolved	ND	ND	45.3	ND	33.9	--	
	Cobalt, Dissolved	ND	ND	0.004	ND	0.001	--	
	Magnesium, Dissolved	ND	ND	17.9	ND	13.3	--	
	Manganese, Dissolved	ND	ND	0.332	ND	0.031	--	
	Molybdenum, Dissolved	ND	ND	0.003	ND	ND	--	
	Nickel, Dissolved	ND	ND	0.138	ND	0.085	--	
	Potassium, Dissolved	ND	ND	6.64	ND	2.81	--	
	Selenium, Dissolved	ND	ND	0.005	ND	ND	--	
	Sodium, Dissolved	ND	ND	71.8	ND	58.7	--	
METEO (in/Hg)	Barometric Pressure	30.09	30.09	30.56	30.42	30.3		
PHYSC	Depth to Water (ft)	10.73	56.74	60.71	60.41	61.3	--	
	Dissolved Oxygen (mg/L)	1.22	3.36	7.09	0.3	6.79	--	
	Dissolved Solids (mg/L)	ND	ND	405	ND	347	--	
	pH (Std Unit)	6.89	6.28	8.01	6.97	6.79	--	
	Redox (mV)	401	333	708	119	447	--	
	Temperature (^{o}F)	64.8	68.6	78.8	63.4	77.6	--	
RADS (pCi/L)	Alpha activity	ND	ND	**125**	ND	**22.9**	MCL	15
	Beta activity	5.03	25.1	**14200**	7.74	**97.3**	MCL	50
	Technetium-99	ND	21.3	**16900**	ND	142	TTL	900
	Uranium	ND	ND	0.01	ND	**0.052**	MCL	0.02
VOA (µg/L)	1,1,1-Trichloroethane	ND	ND	1.7	ND	ND	--	
	1,1-Dichloroethane	ND	ND	20	ND	ND		
	1,1-Dichloroethene	ND	ND	**31**	ND	**7.2**	MCL	7
	1,2-Dichloroethane	ND	ND	1.4	ND	ND		
	Carbon tetrachloride	ND	ND	**62**	ND	ND	MCL	5
	cis-1,2-Dichloroethene	ND	1.3	170000	ND	230	--	
	Methane	ND	ND	1.09	ND	ND	--	
	Trichloroethene	ND	**49**	**77000**	ND	**20000**	MCL	5
	Vinyl chloride	ND	ND	**2200**	ND	ND	MCL	2
WETCHEM	Alkalinity (mg/L)	ND	ND	170	ND	140	--	
	Conductivity (umho/cm)	559	559	1269	716	819	--	
	Silica (mg/L)	ND	ND	29	ND	27		
	Total Organic Carbon (mg/L)	ND	ND	2	ND	1.3	--	
	Turbidity (NTU)	145	117	403	27.1	5999	--	

MCL = maximum contaminant level
NA = no analysis
ND = not detected
PHYSC = physical parameters
TTL = target treatment level for Northwest Plume;
VOA = volatile organic analyte
WETCHEM = wet chemistry parameters
Bold = exceeds criteria
-- = no reference value for this parameter

Environmental Restoration Activities

Northwest Plume Monitoring

The NWPGS started operation in 1995 to initiate control of the highest TCE concentration portion (greater than 1,000 ppb) of the Northwest Plume. Two extraction well fields, each containing two extraction wells, were installed. Each set of extraction wells is surrounded by MWs (Figure 9.6). The network is used for monitoring groundwater quality and water levels to determine the effectiveness of the interim action.

There were no significant TCE concentration changes in the CY 2009 MW data. All MWs indicate that the highest TCE concentration portion of the plume is being controlled. Likewise, ^{99}Tc concentrations in CY 2009 were similar to those measured in CY 2008, and all were less than the 900 pCi/L reference value.

Summaries of the program's monitoring results are listed in Table 9.7. The data for this program are reported in the FFA Semiannual Progress Report.

Northeast Plume Monitoring

The EPA approved an Interim ROD for treatment of the Northeast Plume in June of 1995. The treatment system was completed in 1996 and operation began in 1997 and included two extraction wells, several MWs (Figure 9.7), and facilities required to transfer the TCE-contaminated water to the USEC C-637 Cooling Tower for treatment. Groundwater quality and water-level information obtained from the MWs is used to evaluate the effectiveness of the remedial action. The upgradient MWs also are used to measure ^{99}Tc contamination within the plume before it reaches the extraction wells.

There were no significant TCE concentration changes in the CY 2009 MW data. All MWs indicate that the highest TCE concentration portion of the plume is being controlled when upgradient wells are compared to downgradient wells. Likewise, ^{99}Tc concentrations in CY 2009 were similar to those measured in CY 2008. All ^{99}Tc concentrations were well below the 900 pCi/L reference value.

A summary of the program's monitoring results is listed in Table 9.8. The data for this program are reported in the FFA Semiannual Progress Report.

Groundwater Monitoring Results

The major objectives of groundwater monitoring at the Paducah Site are being met by the monitoring programs. A detectable concentration of analytes, in which the source is associated with the site, has been detected in groundwater off-site. Through the monitoring program, in conjunction with RIs, a footprint of the groundwater contamination has been mapped. The program is modified each year to delineate the boundaries of the contaminant plume 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 contaminants of concern. Contaminants identified by the monitoring program are evaluated by technical assessment and statistical analysis as required by permit, legal agreements, and other standard environmental practices to determine if the source of the contaminants could be from the disposal site being monitored. Found in the off-site and on-site contamination plumes were 1,1-dichloroethane, 1,1-dichloroethene, *cis*-1,2-dichloroethene, alpha and beta activity, PCBs, TCE, ^{99}Tc, and vinyl chloride. 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.

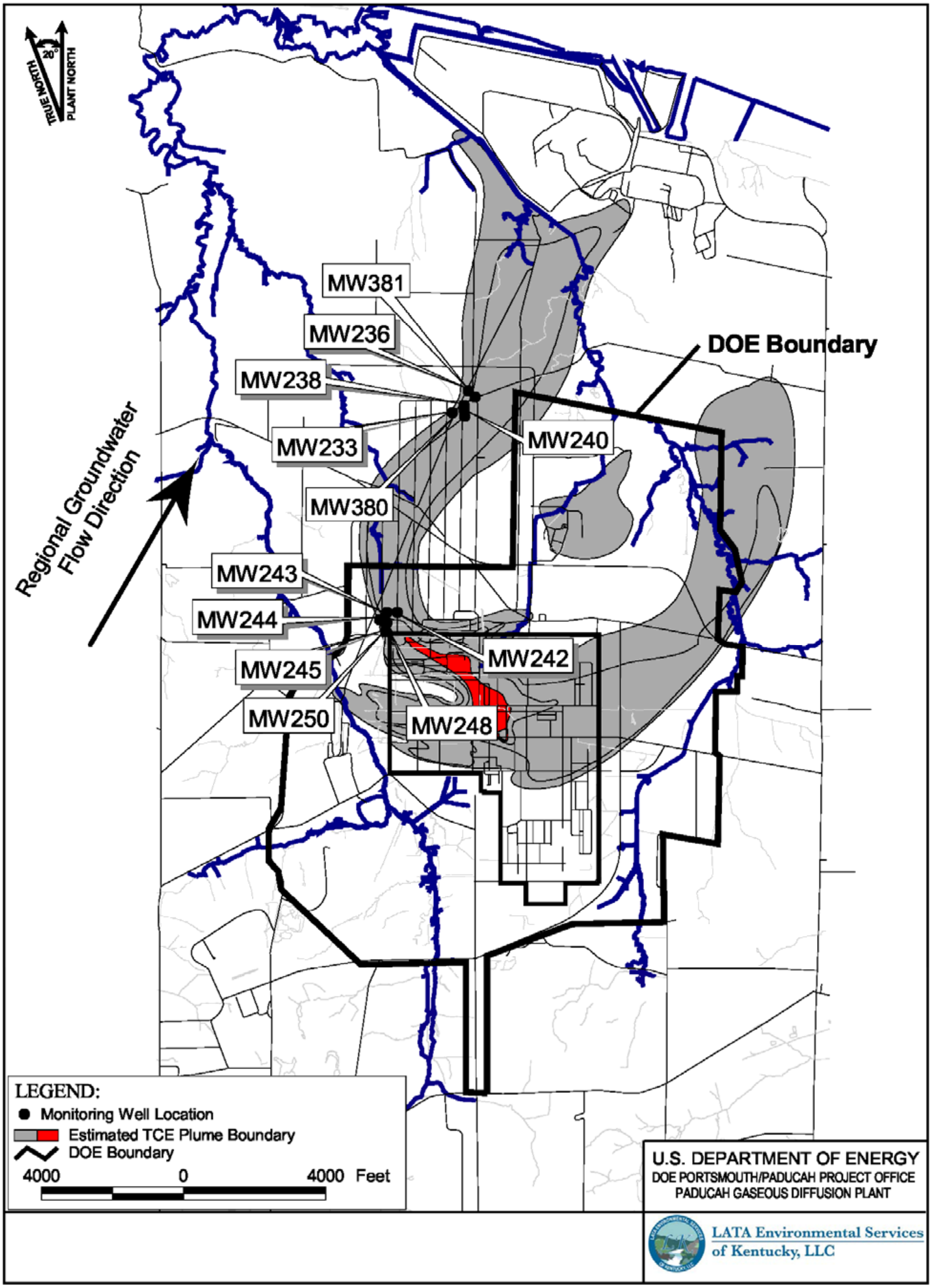

Figure 9.6. Northwest Plume MWs

Table 9.7. Summary of Maximum Groundwater Results from the Northwest Plume Groundwater Monitoring for CY 2009

	Parameter	MW 233	MW 236	MW 238	MW 240	MW 242	MW 243	MW 244	MW 245	MW 248	MW 250	MW 380	MW 381	Reference/ Value	
ANION (mg/L)	Chloride	NA	NA	NA	NA	67	59	NA	NA	NA	NA	NA	39	--	
	Fluoride	NA	NA	NA	NA	0.11	0.1	NA	NA	NA	NA	NA	0.16	MCL	4
	Nitrate as N	NA	NA	NA	NA	ND	1.4	NA	NA	NA	NA	NA	2	MCL	10
	Sulfate	NA	NA	NA	NA	16	13	NA	NA	NA	NA	NA	24	--	
METAL (mg/L)	Arsenic	NA	NA	NA	NA	0.003	0.001	NA	NA	NA	NA	NA	0.002	MCL	0.05
	Barium	NA	NA	NA	NA	0.25	0.152	NA	NA	NA	NA	NA	0.152	MCL	2
	Calcium	NA	NA	NA	NA	27.6	24.6	NA	NA	NA	NA	NA	23.9	--	
	Cobalt	NA	NA	NA	NA	0.002	ND	NA	NA	NA	NA	NA	ND	--	
	Iron	NA	NA	NA	NA	0.529	ND	NA	NA	NA	NA	NA	ND	--	
	Magnesium	NA	NA	NA	NA	11.4	10.2	NA	NA	NA	NA	NA	9.69	--	
	Manganese	NA	NA	NA	NA	0.202	ND	NA	NA	NA	NA	NA	ND	--	
	Molybdenum	NA	NA	NA	NA	0.001	ND	NA	NA	NA	NA	NA	ND	--	
	Nickel	NA	NA	NA	NA	0.021	ND	NA	NA	NA	NA	NA	ND	--	
	Potassium	NA	NA	NA	NA	1.14	1.06	NA	NA	NA	NA	NA	1.35	--	
	Selenium	NA	NA	NA	NA	ND	ND	NA	NA	NA	NA	NA	0.005	MCL	0.05
	Sodium	NA	NA	NA	NA	29.1	24.4	NA	NA	NA	NA	NA	30.3	--	
METAL-D (mg/L)	Arsenic, Dissolved	NA	NA	NA	NA	0.002	ND	NA	NA	NA	NA	NA	ND	--	
	Barium, Dissolved	NA	NA	NA	NA	0.254	0.151	NA	NA	NA	NA	NA	0.154	--	
	Calcium, Dissolved	NA	NA	NA	NA	27.6	25.1	NA	NA	NA	NA	NA	24	--	
	Cobalt, Dissolved	NA	NA	NA	NA	0.002	ND	NA	NA	NA	NA	NA	ND	--	
	Iron, Dissolved	NA	NA	NA	NA	0.118	ND	NA	NA	NA	NA	NA	ND	--	
	Magnesium, Dissolved	NA	NA	NA	NA	11.5	10.4	NA	NA	NA	NA	NA	9.65	--	
	Manganese, Dissolved	NA	NA	NA	NA	0.196	ND	NA	NA	NA	NA	NA	ND	--	
	Nickel, Dissolved	NA	NA	NA	NA	1.11	1.06	NA	NA	NA	NA	NA	1.31	--	
	Potassium, Dissolved	NA	NA	NA	NA	29.5	24.9	NA	NA	NA	NA	NA	30.7	--	
	Sodium, Dissolved	29.9	30.1	29.9	29.9	30.2	30.2	29.8	30.1	29.8	29.8	30.1	30.1	--	
METEO (in/Hg)	Barometric Pressure	45.6	45.0	46.0	45.6	43.9	42.2	39.7	43.0	42.3	41.5	44.5	45.7		
PHYSC	Depth to Water (ft)	3.55	3.72	3.92	3.85	2.79	5.53	4.3	0.76	4.36	5.32	3.83	3.52	--	
	Dissolved Oxygen (mg/L)	NA	NA	NA	NA	219	200	NA	NA	NA	NA	NA	207	--	
	Dissolved Solids (mg/L)	6.2	6.23	6.1	6.18	5.99	6.19	6.32	6.19	6.1	6.21	6.2	6.19	--	
	pH (Std Units)	369	400	397	342	371	375	413	209	409	385	376	378	--	
	Redox (mV)	61	62.7	60.5	60.5	61	61.3	59.7	62.3	60.4	60	60.8	61	--	
	Temperature (°F)	NA	NA	NA	NA	67	59	NA	NA	NA	NA	NA	39	--	

Table 9.7. Summary of Maximum Groundwater Results from the Northwest Plume Groundwater Monitoring for CY 2009 (Continued)

	Parameter	MW 233	MW 236	MW 238	MW 240	MW 242	MW 243	MW 244	MW 245	MW 248	MW 250	MW 380	MW 381	Reference/ Value	
RADS (pCi/L)	Alpha Activity	ND	3.81	ND	2.7	10.3	6.47	ND	ND	3.87	ND	ND	ND	MCL	15
	Beta Activity	ND	14.3	9.84	8.28	142	194	10	7.39	221	13.7	16.1	17.1	MCL	50
	Radon-222	ND	ND	ND	ND	171	195	ND	202	214	ND	ND	ND	--	
	Technetium-99	ND	23.7	ND	ND	143	228	ND	ND	274	24.1	24.7	20.9	TTL	900
VOA (µg/L)	1,1-Dichloroethene	ND	ND	ND	ND	2	ND	1.5	ND	ND	ND	ND	ND	MCL	7
	cis-1,2-Dichloroethene	ND	ND	ND	ND	3	ND	ND	3.7	ND	ND	ND	ND	--	
	Trichloroethene	**6.5**	**32**	**16**	**7.7**	**130**	**310**	**5.1**	**150**	**1400**	**9.3**	**43**	**44**	MCL	5
WETCH EM	Alkalinity (mg/L)	NA	NA	NA	NA	79	70	NA	NA	NA	NA	NA	93	--	
	Conductivity	343	337	337	334	422	373	285	305	361	319	329	379	--	
	Silica (mg/L)	NA	NA	NA	NA	13	15	NA	NA	NA	NA	NA	17	--	
	Total Organic Carbon (mg/L)	NA	NA	NA	NA	1.1	ND	NA	NA	NA	NA	NA	ND	--	
	Turbidity (NTU)	12.2	9.4	38.8	15.2	228	37.6	26.5	163	474	7.7	11.3	9.5	--	

MCL = maximum contaminant level
NA = not analyzed
ND = not detected
PHYSC = physical parameters
TTL = target treatment level for Northwest Plume
VOA = volatile organic analyte
WETCHEM = wet chemistry parameters
-- = No reference value for this parameter
Bold = exceeds criteria

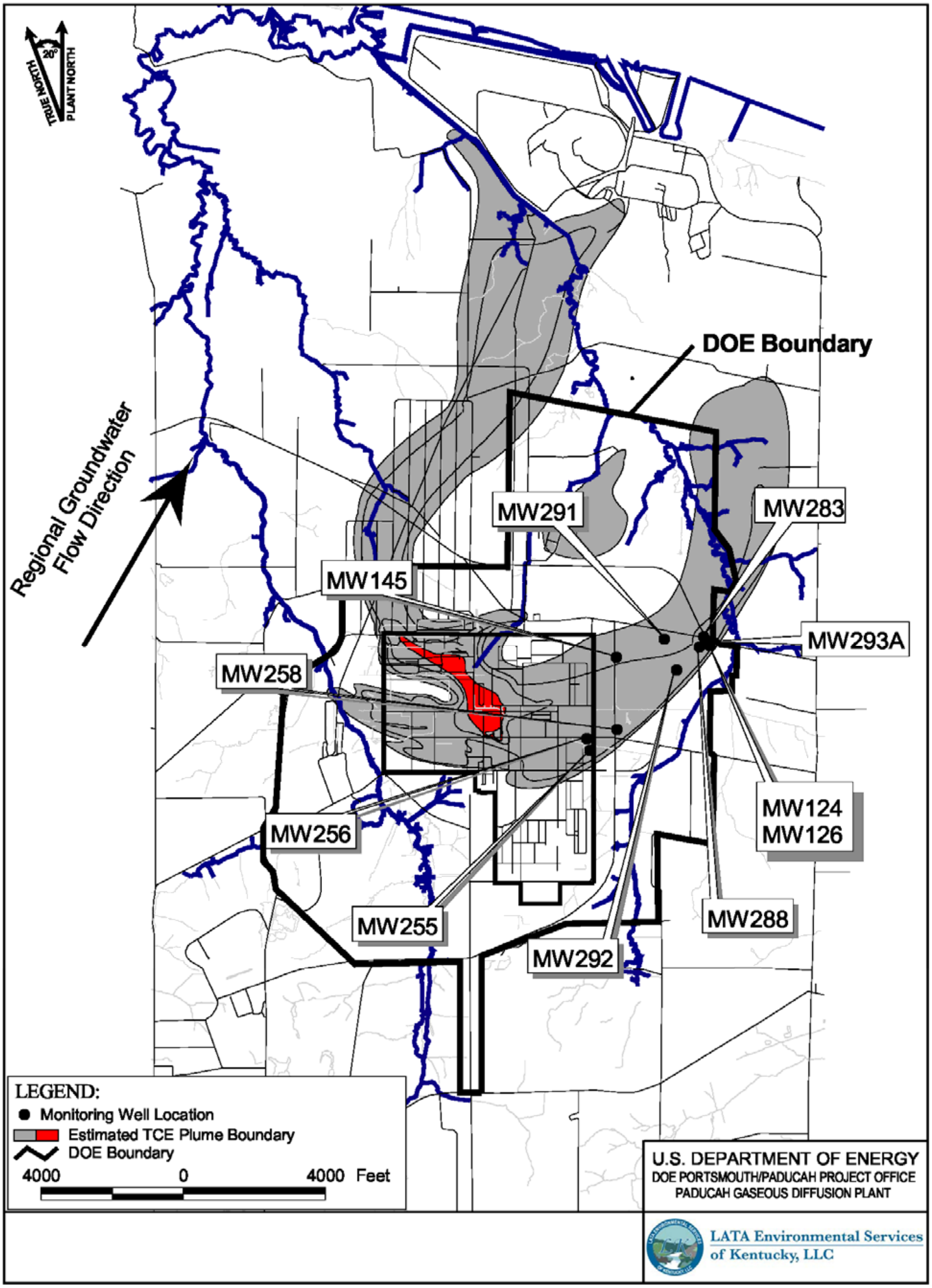

Figure 9.7. Northeast Plume MWs

Table 9.8. Summary of Maximum Groundwater Results from the Northeast Plume Groundwater Monitoring for CY 2009

	Parameter	MW 124	MW 126	MW 145	MW 255	MW 256	MW 258	MW 283	MW 288	MW 291	MW 292	MW 293A	Reference/ Value	
ANION (mg/L)	Chloride			89	59	51	42		68		58		--	
	Fluoride			0.17	0.26	0.23	0.22		0.14		0.18		MCL	4
	Nitrate as Nitrogen					1.3					1.1		MCL	10
	Sulfate			94	42	26	29		20		20		--	
METAL (mg/L)	Aluminum				5.35		3.86						--	
	Barium			0.0621	0.281	0.194	0.17		0.255		0.22		MCL	2
	Calcium			43.7	30.7	27.4	21.9		29.5		25.5		--	
	Chromium			0.166	0.161				0.117		0.025		MCL	0.1
	Cobalt				0.022								--	
	Iron			0.63	7.03		2.17		0.527		0.461		--	
	Lead				0.004								--	
	Magnesium			17.3	12	10.9	8.69		12		10.3		--	
	Manganese				1.49	0.007							--	
	Molybdenum			0.001	0.012				0.012		0.002		--	
	Nickel			0.009							0.012		--	
	Potassium			5.18	2.15	1.82	1.95		1.79		1.67		--	
	Selenium				0.008		0.006		0.006		0.008		MCL	0.05
	Sodium			64.4	83.8	61.4	60.3		42.8		50.4		--	
	Uranium				0.001								--	
METAL-D (mg/L)	Arsenic, Dissolved				0.001								--	
	Barium, Dissolved			0.059	0.141	0.199	0.159		0.266		0.219		--	
	Calcium, Dissolved			44.6	30.1	27.6	22.4		29.9		26		--	
	Cobalt, Dissolved				0.005		0.001							
	Iron, Dissolved				0.111								--	
	Magnesium, Dissolved			17.6	11.7	10.9	8.72		12.2		10.5		--	
	Manganese, Dissolved				0.892	0.007	0.007						--	
	Molybdenum, Dissolved				0.002								--	
	Nickel, Dissolved				0.013		0.0281						--	
	Potassium, Dissolved			5.23	1.63	1.76	1.74		1.73		1.69		--	
	Selenium, Dissolved				0.005		0.006		0.005		0.007		--	
	Sodium, Dissolved			65.4	83.9	61.6	61.8		43.6		51.4		--	
METEO (in/Hg)	Barometric Pressure	30.1	30.1	30.1	30.2	30.3	30.2	30.2	30.2	29.8	30.5	30.1		
PHYSC	Depth to Water (ft)	43.3	39.8	55.1	59.8	60.9	59.6	46.4	47.6	45.5	53.5	41.7	--	
	Dissolved Oxygen (mg/L)	2.27	3.08	1.83	1.05	0.6	1.35	3.8	3.03	4.16	2.2	3.57	--	
	Dissolved Solids (mg/L)			415	377	296	276		267		259		--	
	pH (Std Units)	6.25	6.18	6.17	6.39	6.21	6.34	5.99	6.14	5.77	6.29	6.05	--	
	Redox (mV)	363	369	418	41	376	355	411	389	435	439	381	--	
	Temperature (deg F)	60.4	60.7	67.1	66.2	66.9	66	60.4	65	60.2	64.7	61.6	--	

Table 9.8. Summary of Maximum Groundwater Results from the Northeast Plume Groundwater Monitoring for CY 2009 (Continued)

	Parameter	MW1 24	MW 126	MW 145	MW 255	MW 256	MW 258	MW2 83	MW 288	MW 291	MW 292	MW 293A	Reference/ Value	
RADS (pCi/L)	Alpha Activity							4.31					MCL	15
	Beta Activity	8.05		37.1	5.75	**83.2**	7.79	9.61	32.9		30.3	6.46	MCL	50
	Technetium-99			42.4		132			45.8		55		TTL	900
VOA (µg/L)	1,1-Dichloroethane					17			2.5		5.8		--	
	1,1-Dichloroethene	2.7		1		**130**	3.9	1.2	**22**		**38**		MCL	7
	cis-1,2-Dichloroethene			3.2	9.1	7.2	3	4.6	7	2.5			--	
	Trichloroethene	**80**	**18**	**62**	**370**	**460**	**270**	**84**	**220**	**65**	**300**	**270**	MCL	5
WETCHEM	Alkalinity (mg/L)			120	190	160	140		120		120		--	
	Conductivity (umho/cm)	412	387	712	647	549	487	482	498	367	486	336	--	
	Silica (mg/L)			17	17	16	15		17		18		--	
	Total Organic Carbon (mg/L)			1	1.3								--	
	Turbidity (NTU)	17.6	16.7	26.6	204	67	66.7	46.3	64.6	6.6	58.4	5.9	--	

MCL = maximum contaminant level
NA = not analyzed
ND = not detected
PHYSC = physical parameters
TTL = target treatment level for Northwest Plume
VOA = volatile organic analyte
WETCHEM = wet chemistry parameters
-- = no reference value for this parameter
Bold = exceeds criteria

10 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. Sampling methods, instruments, locations, schedules, and other sampling and monitoring criteria are based on applicable guidelines from various established authorities.

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 comply with quality requirements and assessment standards. Requirements and guidelines for the QA/QC Program at the Paducah Site are established by DOE Order 414.1C, *Quality Assurance;* Commonwealth of Kentucky and federal regulations; and guidance from the EPA, the American National Standards Institute, the American Society of Mechanical Engineers, the 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 is placed on planning, implementing, and assessing activities and implementing effective corrective actions as necessary. Program requirements are specified in project and subcontract documents to ensure that requirements are included in project-specific QA plans and other planning documents. PGDP uses the DOE Consolidated Audit Program (DOECAP) approved labs. The DOECAP implements annual performance qualification audits of environmental analytical laboratories and commercial waste treatment, storage, and disposal facilities to support complex-wide DOE Mission activities.

In 2009, two separate EMPs defined the relationship of each element of the Environmental Monitoring Program. The FY 2009 EMP (PRS 2009a) was in effect and covered data collected during the time frame of January through September 2009. The FY 2010 EMP (PRS 2009b) was in effect and covered data collected during the time frame of October 2009 through December 2009.

In 2009, two separate QA plans defined the relationship of each element of the Environmental Monitoring Program to key quality and data management requirements. The *Environmental Monitoring Quality Assurance Project Plan* and the *Environmental Monitoring Data Management Implementation Plan* in the FY 2009 EMP (PRS 2009a) were in effect and covered data collected during the time frame of January through September 2009. The *Environmental Monitoring Quality Assurance Project Plan* and *Environmental Monitoring Data Management Implementation Plan* in the FY 2010 EMP (PRS 2009b) covered October

2009 through December 2009. Training requirements, sample custody, procedures, instrument calibration and maintenance, and data review are a few of the subjects discussed in the two QA plans.

Field Sampling Quality Control

Data Quality Objectives and Sample Planning

From the start of any sampling program, data quality objectives (DQOs) play an important role in setting the number of samples, location of sampling sites, sampling methods, sampling schedules, and coordination of sampling and analytical resources to meet critical completion times. These sampling program criteria are documented in the Paducah Site EMP (PRS 2009a; PRS 2009b).

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

Field Measurements

Field measurements for the groundwater and surface water monitoring program are collected in the field and include water level measurements, pH, conductivity, flow rate, turbidity, temperature, dissolved oxygen, total residual chlorine, Eh (oxidation/reduction potential) and barometric pressure. Environmental conditions, such as ambient temperature and weather, also are recorded. Field measurements are collected downloaded electronically, recorded on appropriate field forms or recorded in logbooks, and input into PEMS.

Sampling Procedures

Samples are collected using media-specific procedures, which are written according to EPA approved sampling methods. Sample media consist of surface water, groundwater, sediment, and biota, such as deer. Sample information recorded during a sampling event consists of the sample identification number, station (or location), date collected, time collected, and person who performed the sampling, etc. This information, which is documented in a logbook, on a chain-of-custody form, and on the sample container label, then is input directly into PEMS. Chain-of-custody forms are maintained from the point of sampling, and the samples are protected properly until they are placed in the custody of an analytical laboratory.

Field Quality Control Samples

The QC program for both groundwater and environmental monitoring activities specifies a minimum target rate of 5 percent, or one per 20 environmental samples, for field QC samples. Table 10.1 shows the types of field QC samples collected and analyzed. Analytical results of field QC samples are evaluated to determine if the sampling event biased the sample results.

Table 10.1. Types of QC Samples

Field QC Samples	Laboratory QC Samples
Field blanks[a]	Laboratory duplicates
Field duplicates	Reagent blanks
Trip blanks[a]	Matrix spikes[b]
Equipment rinseates[c]	Matrix spike duplicates
	Surrogates
	Performance evaluations
	Laboratory control samples

[a] Blanks = Samples of deionized water used to assess potential contamination from a source other than the media being sampled.
[b] Spikes = Samples that have been mixed with a known quantity of a chemical to measure overall method effectiveness during the analysis process, as well as possible sample/matrix interferences.
[c] Rinseates = Samples of deionized water which have been used to rinse the sampling equipment. It is collected after completion of decontamination and prior to sampling. It is used to assess adequate decontamination of sampling equipment.

Analytical Laboratory Quality Control

Analytical Procedures

When available and appropriate for the sample matrix, EPA-approved SW-846 methods are used for sample analysis. When SW-846 methods are not available, other nationally recognized methods, such as those developed by DOE and ASTM, are used. Analytical methods are identified in a SOW for laboratory services. Using guidance from EPA, laboratories document the steps in sample handling, analysis, reporting results, and follow chain-of-custody procedures.

Laboratory Quality Control Samples

Laboratory QC samples are prepared and analyzed as required by the analytical methods used. Typical laboratory QC samples are identified in Table 10.1. If acceptance criteria are not met for the QC samples, then appropriate action, as denoted by the analytical method, is taken or the analytical data are qualified appropriately.

Independent Quality Control

The Paducah Site is required 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 readily are recognized as objective measures that provide 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 mandatory, 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.

The EPA and KDOW require, as part of their QA program, a laboratory QA study. Each laboratory performing analyses to demonstrate KPDES permit compliance is required to participate. Four laboratories and one sampling organization participated in the study in 2009. Final results for the Discharge Monitoring Report QA Study Number 29 were “acceptable,” with the exceptions of iron. A corrective action report was submitted to EPA in December 2009. The Discharge Monitoring Report QA Study results were provided to KDOW and EPA, as required.

Laboratory Audits/Sample Management Office

Laboratory audits are performed annually by the DOECAP to ensure that the laboratories are in compliance with regulations, methods, and procedures. The audited laboratories are included on the DOECAP-approved listing for use by the Sample Management Office (SMO). Findings are documented and addressed by the audited laboratory through corrective actions.

Data Management

Project Environmental Measurements System

The data generated from sampling events are stored in PEMS, a consolidated site data system for tracking and managing data. The system 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 database for reporting. PEMS uses a variety of references and code lists to ensure consistency and standardization of the data.

Paducah OREIS

Paducah OREIS is the database used to consolidate data generated by the EM 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 the project team and other data users of the available data. Data used in reports distributed to external agencies (e.g., the quarterly landfill reports and the ASER) and they are obtained from Paducah OREIS and have been through the data review process. [The data review process is documented in *Data and Documents Management and Quality Assurance Plan for Paducah Environmental Management and Enrichment Facilities*, DOE/OR/07-1595&D2, Section 8.4 (DOE 1998)].

Electronic Data Deliverables

A "results only" Electronic Data Deliverable (EDD) is requested for all samples analyzed by each laboratory. The results and qualifier information from the EDD are checked in addition to the format of all fields provided. Discrepancies are reported immediately to the laboratory so corrections can be made or new EDDs can be issued. Approximately 10 percent of the EDDs are randomly 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, receipt of any EDD, and comments. The contents of the data package and the chain-of-custody forms are compared and discrepancies identified. Discrepancies are reported immediately to the laboratory and data validators. All data packages are forwarded to the 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, analytes requested, method used, 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 from routine sampling events are validated programmatically at a frequency of 5 percent of the total data packages. Each of the selected data packages, which make up 5 percent of the total number of data packages, is validated 100 percent.

Data assessment is the process for assuring that the type, quality, and quantity of data are appropriate for their intended use based on the DQOs. 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 percent to ensure data are useable. The data assessment is conducted by trained technical personnel 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. During 2009, 18 environmental data packages were validated. Any rejected data identified in the verification or validation process are noted as rejected in OREIS.

The EPA and KDOW require, as part of their QA program, a laboratory QA study. Each laboratory performing analyses to demonstrate KPDES permit compliance is required to participate. Five laboratories and one sampling organization participated in the study in 2009.

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Glossary

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

adsorption–The accumulation of gases, liquids, or solutes on the surface of a solid or liquid.

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 geologic formation, group of formations, or part of a formation capable of yielding a significant amount of groundwater to wells or springs.

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 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 x 10^{10} (37 billion) disintegrations per second. Several fractions and multiples of the curie are used commonly:

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

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 in 40 *CFR* § 141 and 40 *CFR* § 143.

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 received 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 identical 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–Water that is in direct contact with the atmosphere through open spaces in permeable material.

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.

hardness–The amount of calcium carbonate dissolved in water, usually expressed as part of calcium carbonate per million parts of water.

high-level waste–High-level radioactive waste or HLW means: (1) Irradiated reactor fuel, (2) liquid wastes resulting from the operation of the first cycle solvent extraction system, or equivalent, and the concentrated wastes from subsequent extraction cycles, or equivalent, in a facility for reprocessing irradiated reactor fuel, and (3) solids into which such liquid wastes have been converted.

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 or liquids 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 the 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 percent 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 mg/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 7, 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.

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

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

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–An acronym for Radiation Absorbed Dose. The rad is a basic unit of absorbed radiation dose. (This is being replaced by the "gray," which is equivalent to 100 rad.)

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.

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.

troughing system–A collection and containment system designed to collect leaks of oil that have been contaminated with PCBs.

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 that has a low boiling point and readily volatilizes into air (e.g., trichloroethane, tetrachloroethene, and trichloroethene).

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.

Appendix A

Radiation Overview

Abstract

This appendix provides basic information about radiation. This information is intended to be a basis for understanding normal radiation dose from sources unassociated with the Paducah Site. 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**. The atom is thought to consist of a dense central nucleus surrounded by a cloud of electrons. The nucleus is composed of protons and neutrons. Table A.1 summarizes the basic components of an atom. In an electrically neutral atom, the number of protons equals the number of electrons. Atoms can lose or gain electrons through ionization. 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 of the atom.

Atoms of the same element with a different number of neutrons are called **isotopes**. Isotopes have the same chemical properties but different atomic weights. Figure A.1 depicts isotopes of the element hydrogen. Uranium, which has 92 protons, is another example of an element that has isotopes. All isotopes of uranium have 92 protons; however, each uranium isotope has a different number of neutrons. Uranium-234 has 92 protons and 142 neutrons; ^{235}U has 92 protons and 143 neutrons; and ^{238}U has 92 protons and 146 neutrons.

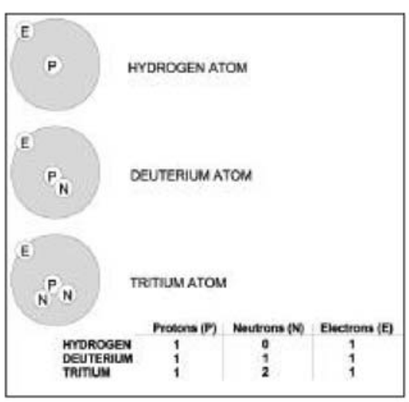

Figure A.1. Isotopes of the Element Hydrogen

Table A.1. Summary of the Basic Parts of an Atom

Particle	Location	Charge	Comments
Protons	Nucleus	+ positive	The number of protons determines the element. If the number of protons changes, the element changes.
Neutrons	Nucleus	No charge	Atoms of the same element have the same number of protons, but can have a different number of neutrons. This is called an isotope.
Electrons	Orbit nucleus	– negative	This negative charge is equal in magnitude to the proton's positive charge.

Basic Information About Radiation

Radioactivity was discovered in 1896 by the French physicist Antoine Henri Becquerel when he observed that the element uranium can blacken a photographic plate, even when separated from the plate by glass or black paper. In 1898, the French chemists Marie Curie and Pierre Curie concluded that radioactivity is a phenomenon associated with atoms, independent of their physical or chemical state. The Curies measured the heat associated with the decay of radium and established that 1 g (0.035 oz) of radium gives off about 100 cal of energy every hour. This release of energy continues hour after hour and year after year, whereas the complete combustion of a gram of coal results in the production of a total of only about 8,000 cal of energy. Radioactivity attracted the attention of scientists throughout the world, following these early discoveries. In the ensuing decades, many aspects of the phenomenon were thoroughly investigated (Encarta 2002a).

Radiation is energy in the form of waves or particles moving through space. Radiation occurs because unstable atoms give off excess energy to become stable. **Ionization** is the process of removing electrons from neutral atoms. NOTE: Ionization should not be confused with radiation. Ionization is a result of the interaction of radiation with an atom and is what allows the radiation to be detected. **Ionizing radiation** is energy (particles or rays) emitted from radioactive atoms that can cause ionization. Ionizing radiation is capable of displacing electrons and changing the chemical state of matter and, subsequently, causing biological damage; therefore, ionizing radiation is potentially harmful to human health. Examples of ionizing radiation include alpha, beta, and gamma radiation. **Nonionizing radiation** bounces off or passes through matter without displacing electrons. Nonionizing radiation does not have enough energy to ionize an atom. It is unclear whether nonionizing radiation is harmful to human health. Examples include visible light, radar waves, microwaves, and radio waves. **Radioactivity** is the process of unstable or radioactive atoms becoming stable by emitting radiant energy. Radioactivity that occurs over a period of time is called **radioactive decay**. The discovery that radium decays to produce radon proved conclusively that radioactive decay is accompanied by a change in the chemical nature of the decaying element. A **disintegration** is a single atom undergoing radioactive decay. **Radioactive half-life** is the time it takes for one-half of the radioactive atoms present to decay.

Types, Sources, And Pathways Of Radiation

Visible light, heat, radio waves, and alpha particles are examples of radiation. When people feel warmth from the sunlight, they actually are 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. The spectrum of particle and electromagnetic radiations ranges from the extremely short wavelengths of cosmic rays and electrons to very long radio waves that are hundreds of kilometers in length. Figure A.2 shows the difference between a longer wavelength and a shorter wavelength. Figure A.3 illustrates the wavelengths of several types of radiation along with an example of something that is approximately the same dimension in length.

The radiation's ability to penetrate material is an important consideration in protecting human health. Adequate shielding decreases the power of radiation by absorbing part or all of it. Figure A.4 shows the different penetrating power of alpha, beta, and gamma rays. Alpha rays are stopped by the thickness of a few sheets of paper or a rubber glove. A few centimeters of wood or a thin sheet of copper stops beta rays. Gamma rays and X-rays require thick shielding of a heavy material, such as iron, lead, or concrete (Encarta 2002b).

Radiation is everywhere. Most occurs naturally, but a small percentage is from man-made sources. Naturally occurring radiation is identical to the radiation resulting from man-made sources.

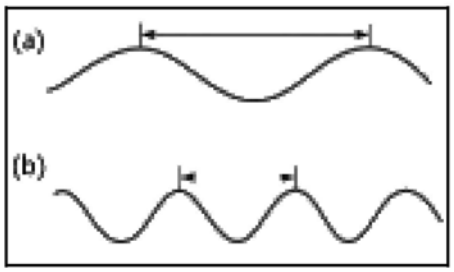

Figure A.2. Comparison between Longer (a) and Shorter (b) Wavelengths[1]

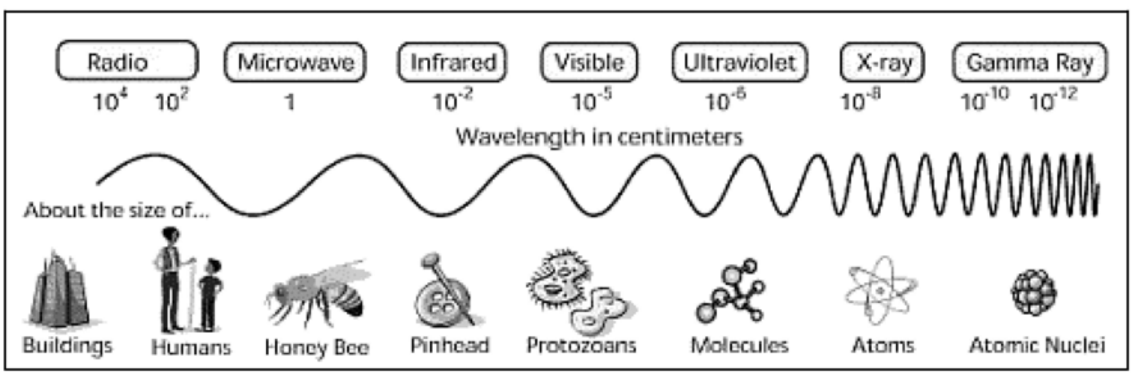

Figure A.3. The Approximate Wavelengths of the Various Regions of the Electromagnetic Spectrum and an Example of Something That Is Approximately the Same Size[2]

[1] ("Electromagnetic…" 2002, Appendix A references)
[2] ("Exploring …" 2002, Appendix A references)

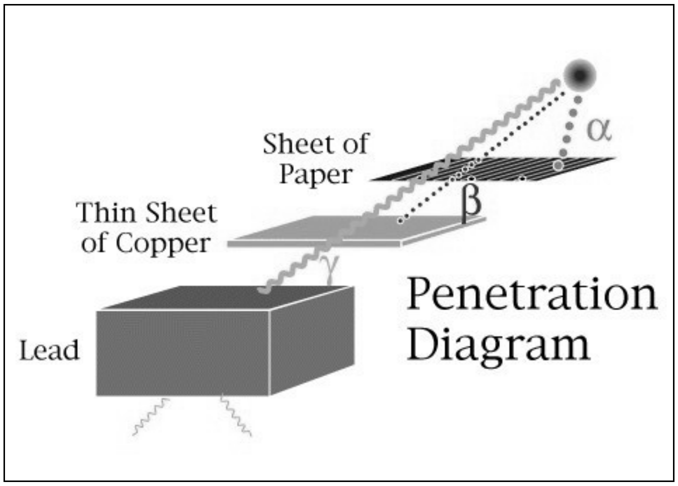

Figure A.4. The Penetrating Potential of the Three Types of Ionizing Radiation: Alpha (α), Beta (β), and Gamma (γ)[3]

Naturally occurring radiation is known as **background radiation**. In fact, this naturally occurring radiation is the major source of radiation in the environment. People have little control over the amount of background radiation to which they are exposed. Background radiation remains relatively constant over time. The amount of 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. Depending on its origin, background radiation is categorized as cosmic, terrestrial, or internal. **Cosmic radiation** comes from the sun and outer space and is made up of energetically charged particles from that continuously hit the earth's atmosphere. Because the atmosphere provides some shielding against cosmic radiation, the intensity of cosmic radiation increases with altitude above sea level. Therefore, a person in Denver, Colorado, is exposed to more cosmic radiation than a person in Paducah, Kentucky. **Terrestrial radiation** refers to radiation emitted from radioactive materials in the earth's rocks, soils, and minerals. Radon (Rn); radon progeny, the relatively short-lived decay products of radium-235 (^{235}Ra); potassium (^{40}K); isotopes of thorium (Th); and isotopes of uranium (U) are the elements responsible for most terrestrial radiation. **Internal radiation** is radiation that is inside the body and is in close contact with body tissue. Internal radiation can deposit large amounts of energy in a small amount of tissue. Radioactive material in the environment enters the body through the air people breathe, the food they eat, and even through an open wound. Natural radionuclides in the body include isotopes of U, Th, Ra, Rn, Pu, bismuth (Bi), and lead in the ^{238}U and ^{212}Th decay series.

In addition, the body contains isotopes of sodium-24 (^{24}Na), ^{40}K, rubidium (Rb), and carbon-14 (^{14}C). Most of our internal exposure comes from ^{40}K. In addition to background radiation, there are man-made sources of radiation to which most people are exposed. Examples include consumer products, medical sources, and other sources. 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** of radiation account for the majority of the exposure people receive from man-made radiation. Radiation is an important tool of diagnostic medicine and treatment. 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

[3] ("Experiment…" 2002, Appendix A references)

preparation of medical instruments, including the sterilization of heat-sensitive products such as plastic heart valves. Nuclear medical 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. **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. Atmospheric testing of atomic weapons has been suspended. About one-half of 1 percent of the United States population performs work in which radiation in some form is present. Radiation and radioactive material in the environment can reach people through many routes. Potential routes for radiation are referred to as **pathways**. Several radiation pathways are shown in Figure A.5. For example, radioactive material in the air could fall on a pasture. Cows could then eat the grass, 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.

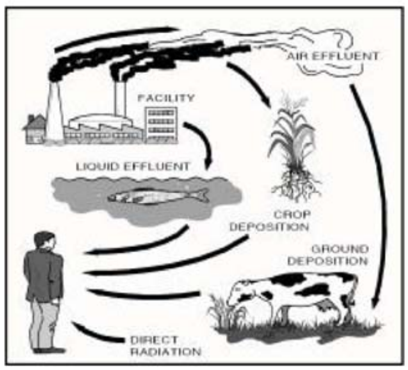

Figure A.5. Possible Radiation Pathways

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. When measuring the amount of radiation in the environment, what actually is 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 one radioactive substance may contain the same amount of activity as several tons of another substance. Activity is measured by the number of disintegrations a radioactive material undergoes in a certain period of time. In the United States, activity is expressed in a unit of measure known as a **curie (Ci)**. In the international system of units, activity is expressed in a unit of measure known as a **becquerel (Bq)**. One disintegration per second (dps) equals one becquerel (Bq). One curie equals:

- 37,000,000,000 atom disintegrations per second ($3.7x10^{10}$ dps)
- 37,000,000,000 becquerels ($3.7x10^{10}$ Bq)
- 1,000,000 microcuries ($1x10^{6}$ µCi)

Dose Information

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 **radiation absorbed dose (rad)**. In the international system of units, 100 rad

= 1 gray. 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. The unit, rad, does not take into account the potential effects that different types of radiation have on the body. 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 **roentgen equivalent man (rem)**. One rem of any type of radiation has the same total damaging effect and pertains to the human body. Dose is expressed in millirems (mrem), because a rem represents a fairly large dose. One millirem is equal to 1/1000 rem. The International System of Units uses the **Sievert (Sv)**, l00 rem = 1 Sievert (Sv), 100 mrem = 1 millisievert (mSv).

Many terms are used to report dose, as listed in Table A.2. 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.

A comparison of some dose levels is presented in Table A.3. 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. 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). The average annual dose received from terrestrial gamma radiation in the United States is about 28 mrem (0.28 mSv). The terrestrial 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 (DOE 1988). The major contributors to the annual dose equivalent for internal radionuclides are the short-lived decay products of radon, mostly Rn-222. 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. Table A.4 presents the internal dose factors for an adult. The United States average annual dose received by an individual from consumer products is about 10 mrem (0.10 mSv) (NCRP 1987). The dose from medical sources includes nuclear medicine examinations, which involve the internal administration of radiopharmaceuticals and generally account for the largest portion of the dose received from man-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). The dose from other sources include small doses received by individuals that 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 (EPA 1984).

Table A.2. Dose Terminology

Term	Description
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 equivalent 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

Table A.3. 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 U.S. from man-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 U.S. 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%.
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* (SRS 1994).

Table A.4. Internal Dose Factors for an Adult

Isotope	Half-life (years)	Intake[a] (mrem/pCi) Inhalation (soluble)	Inhalation (slightly soluble)	Inhalation (insoluble)	Ingestion
^{241}Am	430	NA	5.2E-01	NA	3.64E-03
^{137}Cs	30	3.2E-05	NA	NA	5.00E-05
^{60}Co	5.3	NA	3.0E-05	1.5E-04	1.02E-05
^{237}Np	2,140,000	NA	4.9E-01	NA	4.44E-03
$^{239/240}$Pu	24,000	NA	5.1E-01	3.3E-01	5.18E-05
^{40}K	1,260,000,000	1.2E-05	NA	NA	1.86E-05
^{99}Tc	212,000	8.4E-07	7.5E-06	1.2E-01	1.46E-06
^{230}Th	80,000	UN	3.2E-01	2.6E-01	5.48E-04
^{234}U	247,000	2.7E-03	7.1E-03	1.3E-01	2.83E-04
^{235}U	710,000,000	2.5E-03	6.7E-03	1.2E-01	2.66E-04
^{238}U	4,510,000,000	2.4E-03	6.2E-03	1.2E-01	2.55E-04

[a]Sources: DOE 1988. *Internal Dose Conversion Factors for Calculations of Dose to the Public*, DOE/EH-0071, July.
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NA = not available in the above-referenced documents

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[5] http://www.lbl.gov/abc/experiments/Experiment4.html
[6] http://imagine.gsfc.nasa.gov/docs/science/answers_l2/new_wavelengths.html

Appendix B

Radionuclide and Chemical Nomenclature

Table B.1. Half-Life and Derived Concentration Guide for Selected Radionuclides

Radionuclide	Symbol	Half-life	Ingested Water DCG (µCi/ml)
Americium-241	^{241}Am	432 years	3E-08
Bismuth-210	^{210}Bi	5.01 days	2E-05
Cesium-137	^{137}Cs	30.2 years	3E-06
Cobalt-60	^{60}Co	5.3 years	1E-05
Lead-206	^{206}Pb	Stable	None
Lead-210	^{210}Pb	21 years	3E-08
Lead-214	^{214}Pb	26.8 minutes	2E-04
Neptunium-237	^{237}Np	2,140,000 years	3E-08
Plutonium-239	^{239}Pu	24,110 years	3E-08
Polonium-210	^{210}Po	138.9 days	8E-08
Polonium-214	^{214}Po	164 microseconds	None
Polonium-218	^{218}Po	3.05 minutes	None
Potassium-40	^{40}K	1,260,000,000 years	7E-06
Protactinium-234m	^{234m}Pa	1.17 minutes	None
Radium-226	^{226}Ra	1,602 years	1E-07
Radon-222	^{222}Rn	3.821 days	None
Technetium-99	^{99}Tc	212,000 years	1E-04
Thorium-228	^{228}Th	1.9 years	4E-07
Thorium-230	^{230}Th	80,000 years	3E-07
Thorium-231	^{231}Th	25.5 hours	1E-04
Thorium-234	^{234}Th	24.1 days	1E-05
Uranium-234	^{234}U	247,000 years	5E-07
Uranium-235	^{235}U	710,000,000 years	6E-07
Uranium-236	^{236}U	23,900,000 years	5E-07
Uranium-238	^{238}U	4,510,000,000 years	6E-07

Derived Concentration Guide (DCG) is the concentration of a radionuclide in air or water that would result in an effective dose equivalent of 100 mrem under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation). DCGs do not consider decay products when the parent radionuclide is the cause of the exposure.

Table B.2. Nomenclature for Elements and Chemical Compounds

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^{3-}
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^{2-}
Iron	Fe	Sulfur dioxide	SO_2
Lead	Pb	Thorium	Th
Lithium	Li	Uranium	U
Magnesium	Mg	Zinc	Zn

Units of Radiation Measure

Current System	System International	Conversion
curie (Ci)	becquerel (Bq)	1 Ci = 3.7 x 10^{10} Bq
rad (radiation absorbed dose)	gray (Gy)	1 rad = 0.01 Gy
rem (roentgen equivalent man)	sievert (Sv)	1 rem = 0.01 Sv

Conversions

Multiply	*by*	*to obtain*	*Multiply*	*by*	*to obtain*
in	2.54	cm	cm	0.394	in
ft	0.305	m	m	3.28	ft
mi	1.61	km	km	0.621	mi
lb	0.4538	kg	kg	2.205	lb
gal	3.785	L	L	0.264	gal
ft^2	0.093	m^2	m^2	10.764	ft^2
mi^2	2.59	km^2	km^2	0.386	mi^2
ft^3	0.028	m^3	m^3	35.31	ft^3
acres	0.40468	ha	ha	2.471	acres
dpm	0.45	pCi	pCi	2.22	dpm
pCi	10^{-6}	µCi	µCi	10^{6}	pCi
pCi/L (water)	10^{-9}	µCi/mL (water)	µCi/mL (water)	10^{9}	pCi/L (water)
pCi/m^3 (air)	10^{-12}	µCi/mL (air)	µCi/mL (air)	10^{12}	pCi/m^3 (air)

ha = hectares

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EM Environmental Management

safety ❖ performance ❖ cleanup ❖ closure