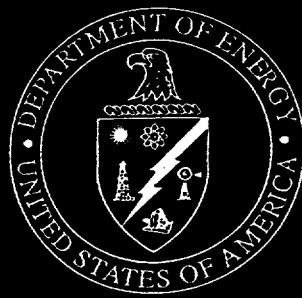




A high-contrast, black and white aerial photograph of a river system. The river curves through a landscape that appears to be a mix of natural terrain and industrial or developed areas, with some linear features suggesting roads or canals. The image is grainy and has a high-contrast, almost graphic quality.

Paducah Site

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Units of Radiation Measure

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

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}	0.0000000000000001	atto-	a	E-18

Photographs courtesy of Vicki W. Jones

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Paducah Site Annual Environmental Report For 1997

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Acronyms and Abbreviations

ACO	administrative consent order
AIP	agreement-in-principle
ATSDR	Agency for Toxic Substance and Disease Registry
Av	average
BBK	Big Bayou Creek
BMP	Biological Monitoring Program
Bq	becquerel
C	degree centigrade
CAA	Clean Air Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	<i>Code of Federal Regulations</i>
Ci	curie
CWA	Clean Water Act
DCG	Derived Concentration Guide
DMR	Discharge Monitoring Report
DNAPL	dense nonaqueous phase liquid
DNFSB	Defense Nuclear Facilities Safety Board
DOE	U.S. Department of Energy
DUF ₆	depleted uranium hexafluoride
EIS	environmental impact statement
EIMS	environmental information management system
Energy Systems	Lockheed Martin Energy Systems, Inc.
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ESD	Environmental Sciences Division
ETTP	East Tennessee Technology Park
F	degrees Fahrenheit
FFC Act	federal facilities compliance act
FFA	federal facilities agreement
FFCA	federal facilities compliance agreement
FIFRA	Federal, Insecticide, Fungicide, and Rodenticide Act
ft	foot
g	gram
Ha	hectare
HSWA	Hazardous and Solid Waste Amendments

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IRA	interim remedial action
K-25	Oak Ridge Gaseous Diffusion Plant
KDAQ	Kentucky Division for Air Quality
KDEP	Kentucky Department for Environmental Protection
KDOW	Kentucky Division of Water
KDWM	Kentucky Division of Waste Management
km	kilometer
KPDES	Kentucky Pollutant Discharge Elimination System
lb	pound
LMES	Lockheed Marietta Energy Systems, Inc.
LUK	Little Bayou Creek
m	meter
m ²	square meter
m ³	cubic meter
MACT	Maximum Achievable Control Technology
MAK	Massac Creek
Max	maximum
Ci	microcurie
g	microgram
Min	minimum
ml	milliliter
mm	millimeter
mrem	millirem
MSDS	material safety data sheet
mSv	millisievert
MW	monitoring well
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NO _x	nitrogen oxides
NOV	notice of violation
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NWPGS	Northwest Plume Groundwater System
OU	operable units
PAT	Proficiency Analytical Testing
PEIS	Programmatic Environmental Impact Statement
PET	Proficiency Environmental Testing
PCB	polychlorinated biphenyls
pCi	picocurie
PGDP	Paducah Gaseous Diffusion Plant

ppb	parts per billion
ppm	parts per million
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RGA	regional gravel aquifer
RI/FS	remedial investigation/feasibility study
ROD	record of decision
SO ₂	sulfur dioxide
SPMD	semi-permeable membrane devices
SS	sediment sample location
SSAB	Site Specific Advisory Board
SW	surface water sample location
SWMU	solid waste management unit
⁹⁹ Tc	technetium-99
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
TSCA	Toxic Substances Control Act
TU _c	chronic toxicity unit
UCRS	upper continental recharge system
UE-FFCA	Uranium Enrichment-Federal Facilities Compliance Agreement
UF ₄	uranium tetrafluoride
UF ₆	uranium hexafluoride
UO ₂	uranium dioxide
USEC	United States Enrichment Corporation
UST	underground storage tank
Utility Services	Lockheed Martin Utility Services
WAG	<ol style="list-style-type: none">1. waste area group2. waste area grouping
WMin/PP	waste minimization/pollution prevention

1. Site and Operation Overview

Abstract

The Paducah Gaseous Diffusion Plant, 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 subsidiary of Lockheed Martin Corporation, Lockheed Martin Utility Services, manages the leased facilities for USEC. The DOE maintains responsibility for the environmental restoration, waste management, and depleted uranium hexafluoride cylinder program activities at the plant through its management contractor. The purpose of this document is to summarize calendar year 1997 environmental monitoring activities for DOE activities at the Paducah Site managed by Lockheed Martin Energy Systems. The DOE requires all of its facilities to conduct and document such activities annually. This report does not include USEC environmental activities.

Introduction

The U.S. Department of Energy (DOE) requires that environmental monitoring be conducted and documented for all of its facilities under the purview of DOE Order 5400.1, *General Environmental Protection Program*. The purpose of this document is to summarize effluent monitoring and environmental surveillance results and compliance with environmental laws, regulations, and orders related to DOE activities at the Paducah Site. During 1997, Environmental Programs at the Paducah Site for 1997 were conducted under the auspices of the Lockheed Martin Energy Systems (Energy Systems) Environmental Management Program.

Environmental monitoring consists of two major activities: effluent monitoring and environmental surveillance. Effluent monitoring is direct measurement or the collection and analysis of samples of liquid and gaseous discharges to the environment. Environmental surveillance is direct measurement or the collection and analysis of samples of air, water, soil, foodstuff, biota, and other media.

Environmental monitoring is performed to characterize and quantify contaminants, assess radiation exposures to members of the public, demonstrate compliance with applicable standards and permit requirements, and detect and assess the effects (if any) on the local environment. Multiple samples are collected throughout the year and are analyzed for radioactivity, chemical content, and various physical attributes.

The overall goal for environmental management is to protect the environment, Paducah Site's neighbors, and to maintain full compliance with all current environmental regulations. The current environmental strategy is to identify any deficiencies and develop a system to resolve them. The long-range goal of environmental management is to minimize the source of pollutants, reduce/eliminate the generation of waste, and minimize hazardous waste by substitution of materials.

Background

Before World War II, the area now occupied by the Paducah Gaseous Diffusion Plant (PGDP) was used for agricultural purposes. Numerous small farms produced various grain crops and provided pasture for livestock. Early in the war, a 6526-ha (16,126-acre) tract was assembled for construction of the

Paducah Site

Kentucky Ordnance Works, which was subsequently operated by the Atlas Powder Company until the end of the war, when it was turned over to the Federal Farm Mortgage Corporation and then to the General Services Administration.

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

Although construction of PGDP was completed in 1954, production of enriched uranium began in 1952. The plant's mission, uranium enrichment, has continued unchanged, and the original facilities are still in operation, albeit with substantial upgrading and refurbishment. Of the 3062 ha (7566 acres) acquired by the Atomic Energy Commission, 551 ha (1361 acres) were subsequently transferred to the Tennessee Valley Authority (Shawnee Steam Plant site) and 1125 ha (2781 acres) were conveyed to the Commonwealth of Kentucky for use in wildlife conservation and for recreational purposes (West Kentucky Wildlife Management Area). Thus, DOE's current holdings are 1386 ha (3423 acres), see Figure 1.1.

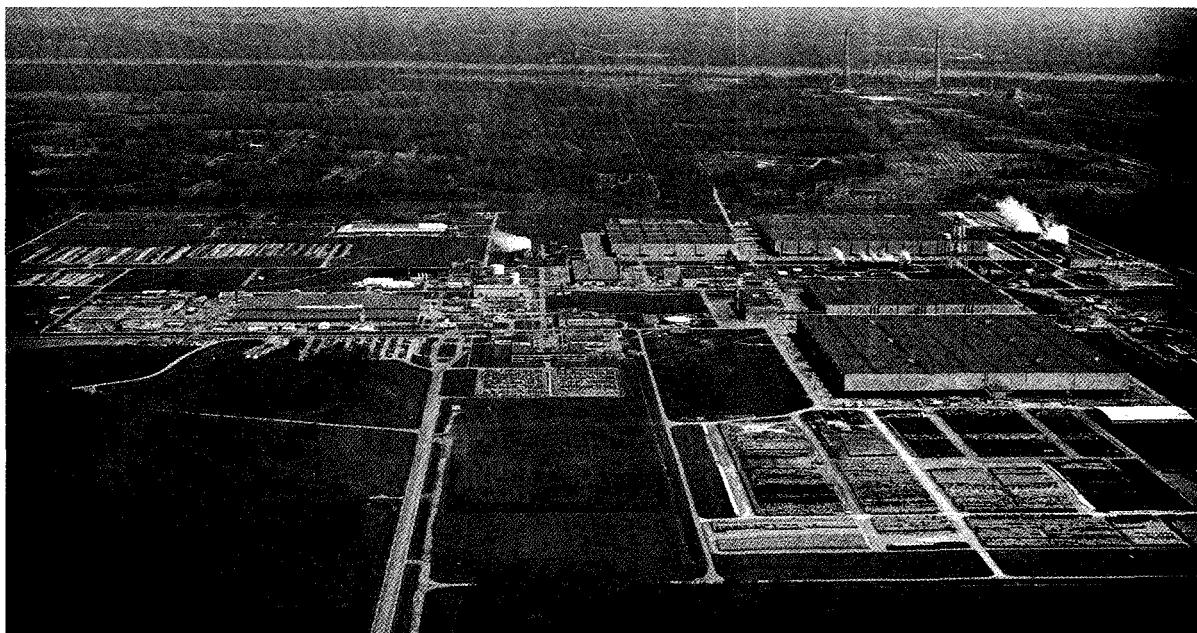


Figure 1.1 Paducah Gaseous Diffusion Plant.

In October 1992, Congressional passage of the National Energy Policy Act established the United States Enrichment Corporation (USEC). Effective July 1, 1993, DOE leased the plant production operations facilities to USEC. Lockheed Martin Corporation created a new subsidiary, Lockheed Martin Utility Services (Utility Services), to manage the leased facilities for USEC under the prior management contract. Under the terms of the lease, USEC has assumed responsibility for compliance activities directly associated with uranium enrichment operations. DOE has retained responsibility for the site Environmental Restoration Program; the Depleted Uranium Hexafluoride Cylinder Program; the majority of the Waste Management Program, including waste inventories predating July 1, 1993; wastes generated by current DOE activities; wastes containing "legacy" constituents, such as asbestos, polychlorinated biphenyls, and transuranics; and Kentucky Pollutant Discharge Elimination System compliance at outfalls not leased to USEC. DOE has also retained manager and cooperator status of facilities not leased to USEC. DOE and USEC have negotiated the lease of specific plant site facilities, written memoranda of agreement to define their respective roles and responsibilities under the lease, and developed organizations and budgets to support their respective functions.

Description of Site Locale

Location

The Paducah Site is located in a generally rural area of McCracken County, Kentucky. The plant is about 16 kilometers (km) (10 miles) west of Paducah, Kentucky, and 4.8 km (3 miles) south of the Ohio River, see Figure 1.2. About 304 hectares (ha) (750 acres) are contained within the security fence where the process buildings (containing the uranium enrichment process equipment) and support facilities are located. An uninhabited buffer zone is provided by an extensive wildlife management area consisting of 850 ha (2100 acres) either deeded or leased to the Commonwealth of Kentucky. An office building in Kevil, which is located in Ballard County, is leased for several Energy Systems organizations. The Kevil facility is about 6 miles from the plant. The population within an 80-km (50-mile) radius of the plant is about 300,500, of which about 39,500 are located within a 16-km (10-mile) radius.

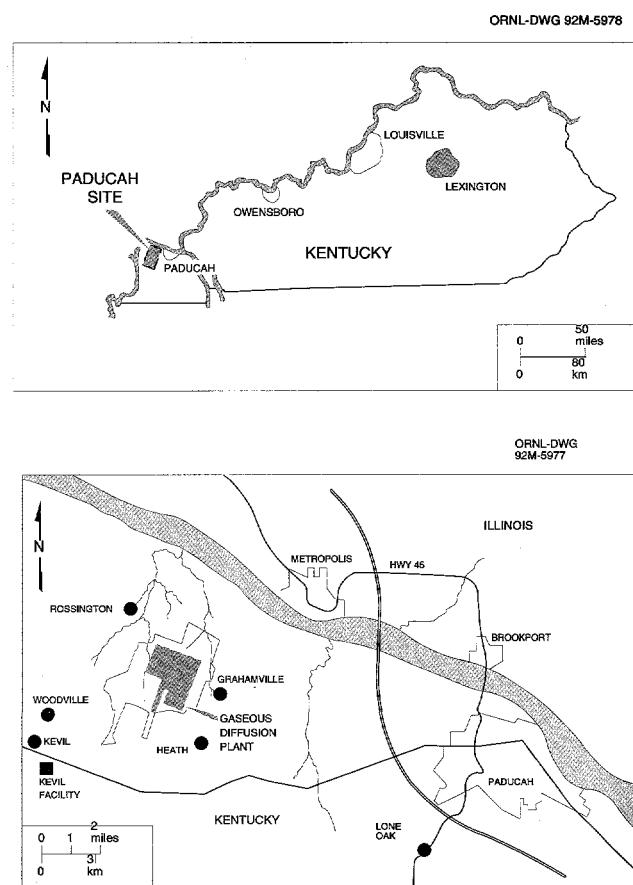


Figure 1.2 Location of the Paducah Site.

Climate

The Paducah Site is located in the humid continental zone where summers are warm [July averages 26 C (79 F)] and winters are moderately cold [January averages 1.7 C (35 F)]. Yearly precipitation averages about 120 centimeters (47 inches). The prevailing wind is from the south-southwest at approximately 16 km (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 24 km (15 miles) upstream of the site, and the confluence of the Ohio River with the Mississippi River is about 56 km (35 miles) downstream. The plant is located on a local drainage divide; surface flow is east-northeast toward Little Bayou Creek and west-northwest toward Big Bayou Creek. Big Bayou Creek is a perennial stream that flows toward the Ohio River along a 14.5-km (9-mile) course. Little Bayou Creek is an intermittent stream that flows north toward the Ohio River along a 10.5-km (6.5-mile) course. The two creeks converge 4.8 km (3 miles) north of the plant before emptying into the Ohio River.

Geology and Hydrology

Soils of the area are predominantly silt loams that are poorly drained, acidic, and have little organic content. The regional gravel aquifer is the uppermost aquifer underlying most of the Paducah Site and the contiguous area north. This groundwater flow system is developed primarily in Pleistocene sands and gravels of the lower member of the continental deposits, occurring between 13 and 33 meters (m) (43 and 100 ft) beneath the plant. The upper member of the continental deposits is predominantly composed of silt and clay with interbedded sand and gravel lenses. A layer of loess three to 10 m (10 to 30 ft) thick overlies the continental deposits at the surface. The continental deposits rest on terraces cut by the ancestral Tennessee and Tennessee-Ohio rivers. Within the regional gravel aquifer, flow is directed north, discharging into the Ohio River.

Ecological Resources

Vegetation

Much of the Paducah Site has been highly disturbed. Vegetation communities on the reservation are indicative of old field succession (i.e., grassy fields, field scrub-shrub, and upland mixed hardwoods).

The open grassland areas, managed by personnel from the West Kentucky Wildlife Management Area, are periodically mowed or burned to maintain early successional vegetation, which is dominated by members of the composite family and various grasses. Management practices on the Wildlife Management Area encourage reestablishment of once common native grasses such as eastern gama grass and Indian grass. Other species commonly cultivated for wildlife forage are corn, millet, Milo, and soybean (CH2M Hill 1991a).

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

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

Wildlife

Wildlife species indigenous to hardwood forests and open grassland communities occur in the vicinity of the Paducah Site. Grassy fields are frequented by rabbits, mice, songbirds, and a variety of other small mammals and birds. Redwing blackbirds, killdeer, cardinals, mourning doves, bobwhite quail, meadowlarks, warblers, sparrows, and red-tailed hawks have been observed in such areas. Shrub-scrub communities support a variety of wildlife, Figure 1.3, including opossums, voles, moles, raccoons, gray squirrels, killdeer, bluejays, redwing blackbirds, bluebirds, cardinals, mourning doves, shrike, warblers, turkeys, and meadowlarks. Deer, squirrels, raccoons, turkeys, songbirds, and great horned owls are found within the mature woodlands of the DOE reservation (CH2M Hill 1991a). The Ohio River serves as a major flyway for migratory birds (SAIC 1992), which along with other transient animals, are occasionally seen on the Paducah Site.

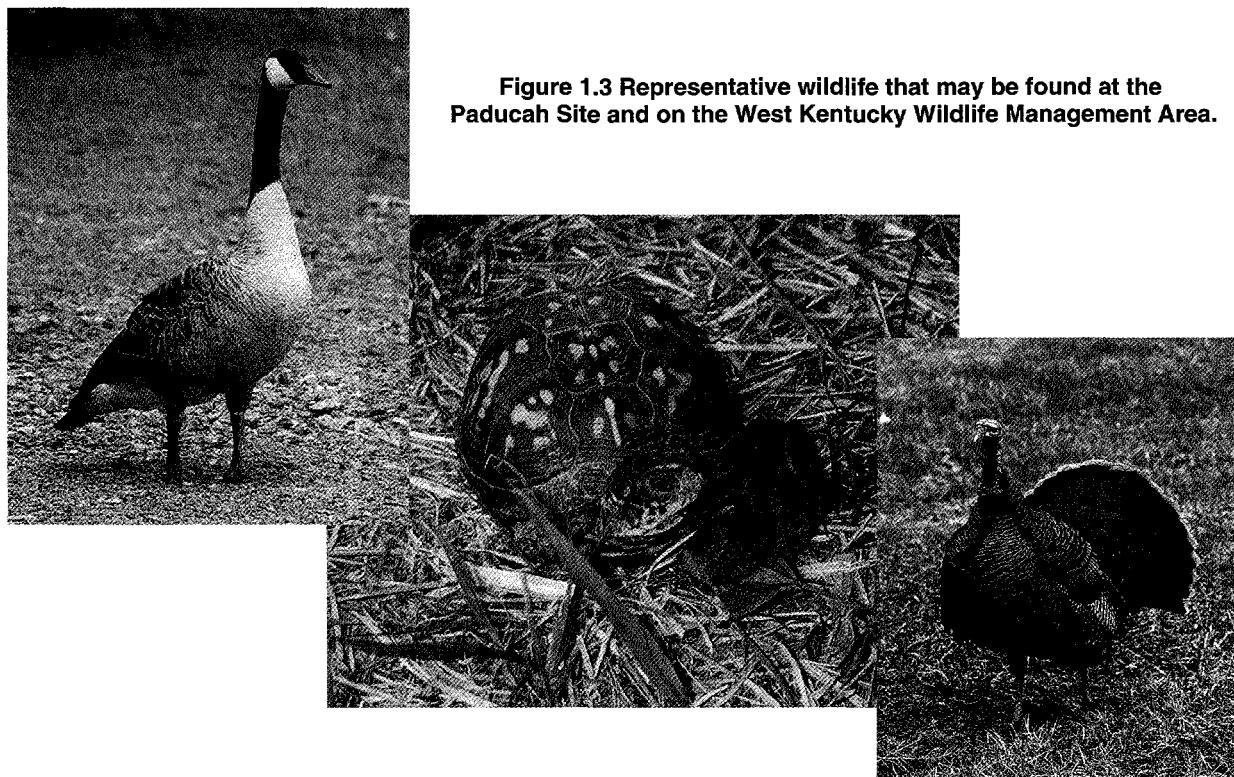


Figure 1.3 Representative wildlife that may be found at the Paducah Site and on the West Kentucky Wildlife Management Area.

Amphibians and reptiles are common throughout the area surrounding the DOE reservation. Amphibians likely to inhabit the area include the American and Woodhouse's toad. Reptiles include the eastern box turtle and several species of snakes (SAIC 1992).

Description of Site Operations and Facilities

In 1997, the DOE, through its operating contractor, Energy Systems, operated the Environmental Restoration, Waste Management, and Enrichment Facilities programs at the plant. The goal of the Environmental Restoration Program is to ensure that releases from past operations and waste management at the Paducah Site are investigated and that appropriate remedial action is taken for protection of human health and the environment in accordance with the Federal Facilities Agreement (FFA). The goal of the Waste Management Program is to characterize and dispose of the legacy waste stored on-site in compliance with various Federal Facilities Compliance Agreements (FFCAs). The goal of the Enrichment Facilities Program is to maintain safe, compliant storage of depleted uranium hexafluoride (DUF₆) pending final disposition of the material as will be addressed in a Programmatic Environmental Impact Statement; to manage facilities and grounds not leased to USEC; in addition to a variety of other projects related to DOE's ownership of the site.

2. Environmental Compliance

Abstract

The policy of the Department of Energy and Lockheed Martin Energy Systems at the Paducah Site is to conduct operations safely and minimize the impact of operations on the environment. Protection of the public, environment, and employees is considered a responsibility of paramount importance.

Introduction

The Paducah Gaseous Diffusion Plant (PGDP) site is owned by the Department of Energy (DOE). Effective July 1, 1993, DOE leased the plant production operation facilities to the United States Enrichment Corporation (USEC). Lockheed Martin Corporation created a new subsidiary, Lockheed Martin Utility Services (Utility Services), to manage the leased facilities for USEC under the prior management contract. Under the terms of the lease, USEC has assumed responsibility for compliance activities directly associated with uranium enrichment operations. Lockheed Martin Energy Systems (Energy Systems) was the management contractor for DOE responsibilities at the site during 1997. These responsibilities include the site Environmental Restoration Program; the Depleted Uranium Hexafluoride (DUF₆) Cylinder Program; the bulk of the Waste Management Program, including waste inventories predating July 1, 1993; wastes generated by current DOE activities; wastes containing "legacy" constituents, such as asbestos, polychlorinated biphenyls (PCBs), and transuranics; and Kentucky Pollutant Discharge Elimination System (KPDES) compliance at outfalls not leased to USEC. DOE has also retained manager and cooperator status of Resource Conservation and Recovery Act (RCRA) storage facilities not leased to USEC. DOE and USEC have negotiated the lease of specific site facilities, prepared memorandums of agreement to define their respective roles and responsibilities under the lease, and developed organizations and budgets to support their respective functions.

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

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

Paducah Site**Table 2.1 Environmental Permit Summary**

Permit Type	Issuer	Expiration Date	Permit Number
<i>Water</i>			
KPDES	Kentucky Division of Water	Oct. 31, 1997	KY0004049
KPDES - Landfill	Kentucky Division of Water	Aug. 31, 2000	KY0100072
Stormwater Point Sources	Kentucky Division of Water	Sept. 30, 1997	KYR100000
<i>Solid Waste</i>			
Residential Landfill (closed)	Kentucky Division of Waste Management	Nov. 1, 1998	073-00014
Inert Landfill (closed)	Kentucky Division of Waste Management	June 11, 1998	073-00015
Solid Waste Contained Landfill (construction/operation)	Kentucky Division of Waste Management	Nov. 4, 2006	073-00045
<i>RCRA</i>			
State Hazardous Waste Management Permit	Kentucky Division of Waste Management	Aug. 19, 2001	KY8890008982
Mod. 12 (01/17/97)	Kentucky Division of Waste Management	Aug. 19, 2001	KY8890008982
Mod. 13 (09/26/97)	Kentucky Division of Waste Management	Aug. 19, 2001	KY8890008982
EPA Hazardous and Solid Waste Amendments Permit	EPA	Aug. 19, 2001	KY8890008982
<i>Air</i>			
Cylinder Refurbishment	Kentucky Division for Air Quality	Aug. 30, 2001	S-96-175
Vortec Cyclone Melting System	Kentucky Division for Air Quality	July 15, 2001	S-96-239

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Compliance Activities

Resource Conservation and Recovery Act

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

RCRA Permit

RCRA Part A and Part B permit applications for storage and treatment of hazardous wastes were initially submitted for the Paducah Site in the late 1980's. At that time, the EPA had authorized the Commonwealth of Kentucky to exclusively administer the RCRA base program for treatment, storage, and disposal units but not the authorization to administer the 1984 Hazardous and Solid Waste Amendments (HSWA) provisions. Therefore, a permit application was submitted to both the EPA and Kentucky Division of Waste Management (KDWM) for treatment and storage of hazardous wastes. On July 16, 1991, a ten-year RCRA permit (No. KY8890008982) was issued by the KDWM and the Environmental Protection Agency for the Paducah Site. This permit, issued to DOE as owner and operator and Energy Systems as a cooperator, authorizes the treatment and storage of hazardous wastes in a number of treatment units, tanks, and container storage areas.

The RCRA permit consists of two individual permits; a hazardous waste management permit administered by the Commonwealth of Kentucky and a HSWA permit administered by the EPA. The hazardous waste management permit issued by the Commonwealth of Kentucky contains regulatory provisions for treatment, storage, and disposal activities authorized under the RCRA base program (pre-HSWA), as well as the HSWA provisions. The EPA HSWA permit addresses only the provisions of the HSWA, which include corrective actions for solid waste management units (SWMUs), air emissions, and the land disposal restrictions. In 1996, Kentucky received authorization to administer the HSWA provisions in lieu of EPA. Even though the state is authorized, the EPA's portion of the RCRA permit will remain in effect until it expires or is rescinded. Therefore, the Paducah Site still has dual requirements for corrective actions under state and federal authority.

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

Modifications to the RCRA Permit

Through December 1997, thirteen (13) permit modifications have been approved to the KDWM Hazardous Waste Management portion of the RCRA permit since issuance in 1991. Two of these modifications occurred in 1997. Modification 12 was the five year permit review and reissuance of the KDWM Hazardous Waste Management Permit. This modification/reissuance incorporates previous modification language, removed references to clean-closed units, and updates tables and text. Modification 13 served to incorporate the changes described in the CERCLA Record of Decision for WAG 17 and corrected, and added to, minor items in various sections.

RCRA Closure Activities

The DOE notified the KDWM of its intent to close the C-746-R Waste Solvent Storage Area starting in November 1997. This unit consists of three storage tanks and a diked concrete storage pad.

RCRA Notices of Violation

The KDWM performed a compliance evaluation inspection in September of 1997. No notices of violation (NOVs) were issued.

Land Disposal Restrictions

Mixed waste (RCRA and radioactive) is generated and stored at the Paducah Site. Such waste is subject to the land disposal restriction storage prohibition that permits storage only for accumulation of sufficient quantities to facilitate proper treatment, recycle, or disposal. Mixed waste is being stored at the Paducah Site because of a nationwide shortage of treatment and disposal facilities for this type of waste. Storage of waste for this purpose does not comply with land disposal restriction regulations. If not for the radioactive constituents, this waste would not pose a compliance problem for the site, as there would be treatment options readily available. Consequently, on June 30, 1992, DOE entered into a federal facilities compliance agreement (FFCA) with EPA Region IV to regulate the treatment and storage of land disposal restriction mixed waste at the Paducah Site.

Solid Waste Management Compliance

The Paducah Site disposes of a portion of its solid waste at its on-site contained landfill facility, C-746-U. Construction of the C-746-U landfill began in 1995 and was completed in 1996. The operation permit was received from KDWM in November 1996. Disposal of waste at the landfill began in February 1997. All wastestreams disposed of at the contained landfill go through a wastestream certification process prior to disposal. DOE and Energy Systems office waste (generated at the plant site) has been combined with USEC and Utility Services office waste prior to off-site disposal. Off-site disposal for the office waste is provided by Liquid Waste Disposal at Calvert City, Kentucky.

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Comprehensive Environmental Response, Compensation, and Liability Act

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

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

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

- TCE and ^{99}Tc were identified as the primary contaminants in off-site groundwater at the Paducah Site.
- A northwest and a northeast groundwater plume extending off site were delineated.
- PCBs and radionuclides were identified as the primary contaminants detected in surface water and sediment in outfalls, ditches, and creeks around the Paducah Site.
- Several on-site sources were identified as potential contributors to off-site contamination.

Risks to human health and the environment from exposure to contamination originating at the Paducah Site were reported in *Results of the Public Health and Ecological Assessment, Phase II* (CH2M Hill 1992b). This report used data collected during the site investigation to quantitatively assess risks to human health and to qualitatively assess risks to the environment. A range of preliminary alternatives that could be used to address the contamination was also developed as part of the ACO activities. This

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information was presented in *Summary of Alternatives for Remediation of Off-Site Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky (Draft)* (SAIC 1991a). Upon completion of the Phase II activities and in response to the risks identified in the public health and ecological assessment, the Paducah Site developed and implemented several interim remedial actions designed to prevent further off-site migration of contaminants and to reduce risks to human health and the environment. The actions targeted certain on-site sources and the off-site contamination associated with groundwater and surface water.

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

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

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

The most significant interim action taken under the ACO, documented in *Technical Memorandum for Interim Remedial Action of the Northwest Plume* (DOE/OR/1031&D2), was developed to evaluate groundwater extraction and treatment to reduce the spread of contamination from the source and high concentration areas of the Northwest Plume. The *Proposed Plan for Interim Remedial Action of the Northwest Plume* (DOE/OR/06-1127&D2), which summarizes the interim alternatives, was approved by the EPA on April 15, 1993. The *Record of Decision for Interim Remedial Action of the Northwest Plume* (DOE/OR/06-1143&D2) was signed by DOE on July 15, 1993, and by the EPA on July 22, 1993. Construction of the interim action (the C-612 Northwest Groundwater Treatment System) was completed and operational on August 28, 1995.

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Other interim actions completed to date include the North-South Diversion Ditch, Institutional Controls for surface water/ditches and scrapyards and the enhancement of the existing cap for Waste Area Group (WAG) 7 - C-746-K Landfill and a removal action at WAG 17 (AOC 124). The North-South Diversion Ditch Interim Action, which is being used to treat certain plant effluents and control the migration of contaminated sediment associated with the ditch, was completed and operational on October 18, 1995. The installation of fencing/posting restricted recreational use of surface water, outfalls and lagoons and the installation of sediment controls to mitigate surface water/sediment runoff from scrap yards has also been completed and is inspected on a monthly basis. The existing cap for the C-746-K Landfill was enhanced to reduce leachate migration from surface infiltration.

The *Record of Decision (ROD) for Interim Remedial Action (IRA) at the Northeast Plume* (DOE/OR/06-1356&D2) was signed by DOE on June 13, 1995, and the EPA on June 1, 1995. The ROD called for the hydraulic containment and treatment of high concentrations of off-site TCE contamination in the Northeast Plume which has been designed and installed. The *Record of Decision (ROD) for Interim Remedial Action (IRA) at Solid Waste Management Units 2 and 3 of Waste Area Group 22 at the Paducah Gaseous Diffusion Plant* (DOE/OR/06-1351&D1) was signed by DOE on August 16, 1995, and by the EPA on August 22, 1995. The ROD for WAG 22 (SWMU 2 - Burial Ground) calls for the installation of an impermeable cap to reduce leachate migration from surface infiltration if data indicates the waste is not at depths that would be in direct contact with groundwater. The action also involves institutional controls and monitoring. During the investigation activities, a determination was made by the state, EPA, and DOE not to install the cap at SWMU 2 as required by the ROD. The waste was determined to be saturated, which meant the effectiveness of the cap would have been uncertain.

On May 31, 1994, the Paducah Site was placed on the EPA National Priorities List (NPL), a list of sites across the nation designated by EPA as a high priority for site remediation. The EPA uses the Hazard Ranking System to determine which sites should be included on the NPL. A site is eligible for the NPL if it ranks 28.5 on the system; the Paducah Site ranked 56.9. Being placed on the NPL means that DOE must follow the cleanup requirements of CERCLA. Section 120 of CERCLA requires federal facilities on the NPL to enter into a federal facilities agreement (FFA), also referred to as an interagency agreement, with the appropriate regulatory agencies. The FFA will serve as a comprehensive procedure for remediation of the Paducah Site and will integrate CERCLA remedial action requirements with RCRA corrective action requirements specified in the RCRA permits. Negotiations with the EPA and the KDEP to finalize the FFA began in June 1993 and were still ongoing in 1997. Once the FFA is finalized, the parties have agreed to terminate the CERCLA ACO because those activities can be continued under the FFA. Under the FFA, DOE is required to submit an annual site management plan to the EPA and KDEP. The plan will summarize the remediation work completed to date, outline remedial priorities, and present schedules for completing future work.

Agency for Toxic Substances and Disease Registry (ATSDR), based in Atlanta, Georgia, is part of the U. S. Public Health Service. As required by CERCLA, the agency conducts public health assessments of hazardous waste sites listed or proposed for listing on the NPL. ATSDR representatives made their initial site visit to Paducah in May 1994 for the purpose of assigning a ranking to the site for priority in scheduling the health assessment. A "B" ranking was assigned to Paducah, which is the second highest priority. The ranking was based on groundwater contamination, associated with the plant,

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that had affected several off-site wells. The ATSDR is aware of the actions the site has taken since 1988 to remove the risk of drinking and using this contaminated water.

In 1995, the ATSDR visited the Paducah Site to initiate a public health assessment (PHA). In June of 1997, representatives of the ATSDR met with the Site Specific Advisory Board (SSAB) to discuss the ATSDR PHA. ATSDR representatives also met with AIP representatives and one citizen (at their request). During the year, the ATSDR representatives became more familiar with the area around the plant, received copies of numerous documents, and met informally with a few individual farmers.

By late 1997, the ATSDR was drafting sections of the PHA as they still reviewed documents and data for other sections.

CERCLA Notices of Violation

No CERCLA NOVs were received in 1997.

CERCLA-Reportable Quantities

There were no spills of a CERCLA reportable quantity at the Paducah Site in 1997.

Federal Facilities Compliance Act

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

To facilitate compliance with the FFC Act and address the myriad of complex issues involved, the Paducah Site, along with 48 other DOE sites, began a four-phase approach. The first phase consisted of gathering required information and submitting to the EPA and state agencies an inventory of mixed wastes (mixed waste inventory report), including information pertaining to characterization and waste generation volumes. The second phase involved the development of a Conceptual Site Treatment Plan. The plan included investigation of the existing treatment capacity for facility wastes and, where there was no existing capacity, procurement of information on potential treatment technologies or options that could be employed to meet operation requirements. The Paducah Site submitted the Conceptual Site Treatment Plan in October 1993. The third phase expanded on the information in the Conceptual Site Treatment Plan to identify treatment options that are preferred both environmentally and economically. The information gathered by the ongoing waste characterization program and the technology evaluation

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and development program outlined in the Conceptual Site Treatment Plan formed the basis for the draft Site Treatment Plan, which was submitted to the regulators in August 1994. The fourth phase is to combine the preferred treatment options from the draft Site Treatment Plan with regulator and stakeholder comments and the overall DOE complex picture to formulate a proposed Site Treatment Plan. This proposed Site Treatment Plan was submitted to the regulators on March 31, 1995, and provides details on how and where Paducah Site mixed waste is to be treated.

On October 4, 1995, KDWM issued a Unilateral Order and Site Treatment Plan for the Paducah Site. On November 3, 1995, the DOE appealed the Unilateral Order due to requirements of the Residual Management Contingency Plan and funding language in the Order. The appeal has been agreed upon. The site is in compliance with the Site Treatment Plant.

FFC Act NOVs

The Paducah Site is in compliance with the FFC Act. No NOVs were received during 1997.

Toxicity Characteristic Leaching Procedure FFCA

The Paducah Site has generated a significant volume of waste materials that are stored on-site. A large quantity of this waste was generated, characterized, and placed in storage before September 25, 1990, when the toxicity characteristic regulations, *Title 40, Code of Federal Regulations, Part 261.24* (40 CFR 261.24), became effective. The site had accumulated a significant volume of solid wastes that had not been characterized under the new toxicity characteristic regulations and that was not stored in RCRA-regulated units. DOE needed revised characterization of these wastes by the new protocol.

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

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

A three-phase program for accomplishing the goals of the plan is under way. Phase I activities consist of data compilation and waste prioritization. Phase II involves identification of discrete waste streams and

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development of characterization plans. The final phase of the program includes the development of sampling and analysis plans, field sampling, and data reporting.

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

Toxicity Characteristic Leaching Procedure FFCA NOVs

The Paducah Site is in compliance with the toxicity characteristic leaching procedure FFCA. No NOVs were received during 1997.

Underground Storage Tanks

Underground storage tanks (USTs) at the Paducah Site were used to store petroleum products, such as gasoline, diesel fuel, and waste oil. These tanks are regulated under Subtitle I and Subtitle C of RCRA. State Superfund regulations apply to tanks not covered by the UST regulations.

The UST program includes 15 USTs, the status of which follows:

- Closed USTs (eight)- Five USTs were closed under the Waste Area Group (WAG) 7 project. The Kentucky Department of Environmental protection approved no further action on these USTs in a letter dated December 6, 1996. One UST was closed pursuant to RCRA, Subtitle C. RCRA closure was approved by the KDWM on June 20, 1994. Two USTs have been removed and are being closed pursuant to the UST closure plan. Final closure activities are planned for the summer of 1998.
- HSWA permit-deferred USTs (five) - Five tanks in WAG 15 were sampled in 1996 for potential closure in place under the state UST regulations. Further sampling of some of the tanks is scheduled for the summer of 1998. It is noted that the Paducah Site has been allowed to defer the investigations for these tanks to the HSWA permit until Environmental Restoration Program addresses the tanks through the Corrective Actions or CERCLA programs.
- USTs excluded from regulation (two) - Two USTs are part of a waste water treatment system and are excluded from UST regulations.

UST Program NOVs

No UST NOVs were received in 1997.

National Environmental Policy Act

The National Environmental Policy Act (NEPA) provides a means to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions.

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Compliance with NEPA, as administered by NEPA Implementing Procedures (10 CFR 1021) and Council on Environmental Quality Regulations (40 CFR 1500–1508), ensures that consideration is given to environmental values and factors in federal planning and decision making. To strengthen its NEPA review and documentation process, DOE promulgated new NEPA regulations on July 9, 1996. These new regulations streamline the NEPA requirements while maintaining quality and maintain consistency with the DOE Secretary Policy Statement on NEPA issued in June 1994.

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

In 1997, the DOE Oak Ridge Operations Office determined that seven actions at the Paducah Site were categorically excluded review from further NEPA. In addition, 19 other proposed activities were approved internally by applying previously approved categorical exclusions. The Paducah DOE Site Office and the DOE Oak Ridge Operations Office NEPA Compliance Officer approve and monitor the internal applications of previously approved categorical exclusion determinations. The Paducah Site used five previously approved categorical exclusions for activities such as routine maintenance and small-scale modifications.

On October 22, 1997, DOE decided to prepare an environmental assessment (EA) for the treatment of mixed wastes at the Paducah Site using the Vortec vitrification system. Argonne National Laboratory was selected to prepare the EA for DOE. A nationwide Final Waste Management Programmatic Environmental Impact Statement (PEIS) was issued by DOE in May 1997, (DOE/EIS-0200-F). DOE did not issue any records of decision based on the PEIS in 1997. Records of decisions for the PEIS could determine the method of disposition of waste currently stored at the Paducah Site. DOE also continued preparation of another national PEIS for management of depleted uranium hexafluoride. A record of decision from the PEIS could affect the disposition of the cylinders currently stored at the Paducah Site, as well as those in Oak Ridge, Tennessee and Portsmouth, Ohio. The Paducah Site has assisted in preparation of these PEISs by providing site information.

Other Environmental Acts, Regulations, and Statutes

National Historic Preservation Act

The National Historic Preservation Act (NHPA) of 1966 is the primary law governing federal agencies' responsibility for identifying and protecting historic properties (cultural resources included in, or eligible for inclusion in, the National Register of Historic Places). There are currently no historic properties at the Paducah Site in the National Register of Historic Places, although there is a potential for eligible historic properties. Therefore, each proposed project is assessed to determine if there are any historic properties present and whether they may be affected. In making these determinations, DOE consults with the State Historic Preservation Officer (SHPO) as required by Section 106 of the National Historic Preservation Act.

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

In 1997, no activities were conducted which adversely affected historic properties.

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, field surveys are performed to identify threatened and endangered species and their habitats, and mitigating measures are designed as needed. When appropriate, DOE initiates consultation with the U. S. Fish and Wildlife Service prior to implementing a proposed project.

Eleven federally-listed, proposed, or candidate species have been identified as potentially occurring at or near the Paducah Site. In 1997, DOE projects at the Paducah Site did not directly impact any of these 11 species. Potential habitats of these species were also not significantly impacted. DOE initiated informal consultation with the U. S. Fish and Wildlife Service for some projects.

In 1997, DOE activities at the Paducah Site were conducted in compliance with the Endangered Species Act.

Floodplain/Wetlands Environmental Review Requirements

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

In 1997, no floodplain or wetlands assessments were prepared or approved. Also, no floodplain or wetlands notices of involvement were published in the *Federal Register* for the Paducah Site. In addition, DOE did not apply for any individual permits from the Corps of Engineers or for any water

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quality certifications from the state. Some DOE projects were authorized by the Corps of Engineers general nationwide permits for activities involving waters of the United States.

DOE activities did not result in significant impacts to floodplains or wetlands at the Paducah Site in 1997.

Farmland Protection Policy Act

Prime farmland is generally defined as land that has the best combination of physical and chemical characteristics for producing crops of statewide or local importance. The Farmland Protection Policy Act of 1981 requires federal agencies to consider the effects of their proposed actions on prime farmland and consider any alternatives that would lessen impacts. When required, prime farmland surveys are conducted, and DOE consults with the U. S. Department of Agriculture Natural Resources Conservation Service, formerly the Soil Conservation Service. If conversion of prime farmland is anticipated, a Farmland Conversion Impact Rating form is completed and submitted to the Natural Resources Conservation Service. No Farmland Conversion Impact Rating forms were submitted to the Natural Resources Conservation Service in 1997.

DOE activities did not result in conversion of any prime farmland in 1997.

Clean Water Act

The Clean Water Act (CWA) was established primarily through the passage of the Federal Water Pollution Control Act Amendments of 1972. The CWA established four major programs for control of water pollution: (1) a permit program regulating point-source discharges into U.S. waters, (2) a program to control and prevent spills of oil and hazardous substances, (3) a program to regulate discharges of dredge and fill materials into U.S. waters, and (4) a program to provide financial assistance for construction of publicly owned sewage treatment works.

Kentucky Pollutant Discharge Elimination System

The CWA applies to all nonradiological discharges to navigable surface waters. At the Paducah Site, the regulations are applied through two KPDES permits for effluent discharges to Big Bayou and Little Bayou creeks. The Kentucky Division of Water (KDOW) issued KPDES Permit No. KY0004049 to the PGDP in September 1992. This permit became effective on November 1, 1992, and is enforced by the KDOW. In June 1993, the KDOW added USEC as a joint owner of the permit. At the request of the Paducah Site, the Commonwealth of Kentucky granted a stay of permit limits for pH, metals, and temperature in October 1992. An Agreed Order was signed with the Natural Resources and Environmental Protection Cabinet on April 5, 1996. As a part of the Agreed Order, pH, temperature, and metals studies were carried on during 1996 and 1997. The pH and temperature studies were completed in 1997. The studies indicated USEC discharges were effecting the pH and temperature in receiving streams. USEC is implementing temperature and pH controls for effluent discharges. DOE outfalls were not effecting receiving streams. The metals study is ongoing with inconclusive results during 1997.

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The KDOW issued KPDES Permit No. KY0100072 on July 26, 1995, although the permit did not become effective until September 1, 1995. This is a DOE held permit for the C-746-U Contained Landfill. The permit covers surface water runoff from the landfill and is written to identify leachate constituents that may be released from the capture system into the sedimentation lagoon. The landfill became operational in January of 1997.

Due to the large retention area of the C-746-U surface water containment structure and administrative controls of the pond, discharges from the sediment pond occurred only during March, July, and November of 1997. One exceedence of the pH discharge standard occurred during July. Because of a heavy algae bloom in the pond during the July discharge the discharge pH was found to be 9.2 standard pH units. The maximum permit limit for pH is 9.0 standard units.

As part of the DOE/USEC transition, DOE retained responsibility for any historic environmental problems that were the result of plant operations before July 1993. In February of 1997, the trichloroethylene concentration measured in USEC's outfall 011 was measured at 0.085 mg/l. The discharge limit is 0.081 mg/l. Trichloroethylene is considered to be a historic problem for which DOE is responsible. The trichloroethylene level in outfall 011 increases each year since 1992 in the March, April, May timeframe. The current hypothesis based on water table data is that during the spring when the perched water table which is contaminated with trichloroethylene rises, it acts as a recharge to outfall 011 resulting in an increase in outfall discharge concentrations. DOE also retained responsibility for two of the 18 KPDES outfalls listed on the jointly held permit. Those two outfalls (017 and 018) are comprised solely of storm water runoff and contain no process wastewater. No exceedences of effluent limits occurred in 1997 at these two DOE outfalls. All of the analytical results for water generated from environmental restoration activities (i.e., DOE activities) were reviewed for KPDES compliance by Utility Services for USEC before being released to USEC KPDES outfall 001. Increased priority has been placed on erosion control at construction projects to greatly reduce the release of suspended solids from all construction projects at the Paducah Site. The compliance rate was 100% for DOE's outfall 018 with the KPDES Permit Number KY0004049 during 1997. The compliance rate for outfall 017 was 97% with one noncompliance occurring in March with the oil and grease limit, and one noncompliance with the pH limit in October of 1997. The oil and grease limit was probably exceeded due to a leaking piece of equipment or vehicle. An investigation following the discovery of oil and grease in the outfall failed to find a source and subsequent sampling showed no oil and grease present. The pH noncompliance in October was the result of concrete dust entering outfall 017 with rainfall run off from a UF6 cylinder yard construction activity. Controls were in place at the time of the noncompliance to control discharges, but were insufficient to control a very large rainfall event associated with a large sawing operation that had resulted in significant quantities of concrete dust.

In addition, USEC initiated the return of outfalls 001 and 015 to DOE ownership in the spring of 1997 although the lease agreement was not modified to reflect this change until May 13, 1998. One noncompliance of the toxicity limit of 1 toxicity unit (TU_c) occurred at outfall 001 in August of 1997. The cause was not determined and required follow up testing indicated toxicity was intermittent.

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CWA NOVs

No CWA NOVs were received in 1997.

Toxic Substances Control Act

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

Polychlorinated Biphenyls

The Paducah Site TSCA Compliance

Program focuses on maintaining compliance with PCB regulations (40 CFR 761). The program concentrates on two major functions: (1) producing compliance documents and reports and (2) providing guidance to site organizations.

The Uranium Enrichment FFCA (UE-FFCA) between the EPA and DOE was signed in February 1992. To meet the compliance goals at the Paducah Site, the UE-FFCA is frequently revised and updated. Under this agreement, action plans have been developed and implemented for removal and disposal of large volumes of PCB material at the Paducah Site. As part of this program during 1997, 420 capacitors were removed from service. Table 2.2 shows progress of removal of capacitors in service during the year. Table 2.3 is a summary of PCB items in service at the Paducah Site as of the end of 1997.

Short-term plans include pursuing EPA approval for a PCB-drum wash station to decontaminate PCB containers. The annual PCB report, due July 1,

Table 2.2 Status of large, high-voltage PCB capacitors at Paducah in 1997

Building location	Beginning balance, 1/1/97	Capacitors removed	New balance 12/31/97
C-331	69	0	69
C-333	913	98	815
C-335	80	34	46
C-337	1,394	288	1,106
Total	2,456	420	2,036

Table 2.3 Summary of PCBs and PCB items in service at Paducah at the end of 1997

Type	Number in Service	Volume (gal)	PCBs (kg)
PCB transformers	66	95,316	277,156.3
PCB contaminated transformers	24	7,649	4.3
PCB contaminated electrical equipment	18	4,704	5.0
PCB capacitors	2,036		
PCB open systems ^a	3	235	10.9

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

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provides details of facility activities associated with the management of PCB materials. The annual report provides details from the previous year on all PCB items that are in use, stored for reuse, generated as waste, stored for disposal, or shipped off-site for disposal. All Paducah Site UE-FFCA milestones for 1997 have been completed.

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

TSCA NOVs

No TSCA NOVs were received in 1997.

Federal Insecticide, Fungicide, and Rodenticide Act

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) regulates the manufacture, storage, and application of registered pesticides. No restricted-use pesticides are used by Paducah Site personnel. If application of a restricted-use pesticide at the plant should be necessary for DOE activities, a certified contractor will be used. General-use pesticides are applied by plant personnel in a manner consistent with product labeling; all product warnings and cautions are strictly adhered to. Applications of pesticides by PGDP and contractor personnel must be approved by the PGDP pesticide coordinator.

FIFRA NOVs

No FIFRA NOVs were received in 1997.

Emergency Planning and Community Right-To-Know Act

The Emergency Planning and Community Right-To-Know Act (EPCRA), also referred to as the Superfund Amendments and Reauthorization Act, Title III, requires reporting of emergency planning information, hazardous chemical inventories, and releases to the environment. EPCRA reports are submitted to federal, state, and local authorities. Executive Order 12856, signed in August 1993, subjects all federal agencies to EPCRA. The ongoing requirements of EPCRA are contained in Sections 304, 311, 312, and 313.

- Section 304 requires reporting of off-site reportable quantity releases to state and local authorities.
- Section 311 requires that either material safety data sheets (MSDSs) or lists of the hazardous

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- chemicals for which an MSDS is required be provided to state and local authorities for emergency planning purposes.
- Section 312 requires that a hazardous-chemical inventory be submitted to state and local authorities for emergency planning.
- Section 313 requires annual reporting of releases of toxic chemicals to the EPA and the state.

The Paducah Site had no releases subject to Section 304 notification requirements during 1997. The Section 311 MSDS lists are updated frequently and provided to the appropriate officials. The Section 312 Tier II report of inventories for 1997, included uranium hexafluoride (UF_6), uranium tetrafluoride (UF_4), diesel fuel, kerosene, magnesium fluoride, and PCB's associated with DOE activities. Under Section 313, only one chemical was reported. Approximately 78 pounds of zinc dust resulting from the cylinder painting project was released to the environment as air emissions. These zinc emissions were in compliance with an air permit issued by the Kentucky Division for Air Quality (KDAQ).

EPCRA NOVs

No EPCRA NOVs were received in 1997.

Clean Air Act

Authority for enforcing compliance with the Clean Air Act (CAA) and subsequent amendments reside with the EPA and the Kentucky Division for Air Quality (KDAQ). The EPA generally enforces rules resulting from Title VI (Stratospheric Ozone Protection) of the Clean Air Act. The Paducah Site has an ongoing program to maintain compliance with all federal and state rules resulting from the CAA and its amendments.

Clean Air Act Permit Status

The Paducah Site DOE facilities had three general areas of point source air emissions in 1997. The Northwest Groundwater Treatment System released approximately 3401 pounds of trichloroethylene (TCE), a clean air act hazardous air pollutant. Approximately 658 pounds of TCE were also released from the C-337 Cooling Tower, a part of the Northeast Groundwater Treatment Facility. The operation of these facilities are interim remedial actions for the cleanup of groundwater contamination at the Paducah Site. These facilities remove TCE contamination from the groundwater with an air stripper and release the TCE to the atmosphere, where it will naturally breakdown.

The third area of emissions was from depleted UF_6 storage cylinder refurbishment. DOE began repainting cylinders in order to minimize corrosion which could result in a breach of the cylinder vessel and subsequent exposure of UF_6 to the environment. Cylinder refurbishment consists of steel grit blasting any rust and scale, followed by spray painting. There are several point sources of air emissions for the refurbishment operation. Approximately 3000 pounds of volatile organic compounds, a CAA criteria pollutant, were released by the cylinder painting. The steel grit blasting generated less than 5 tons of particulate emissions (rust), another criteria pollutant.

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The KDAQ issued an air permit for the cylinder refurbishment operations on April 22, 1996. The permit was revised on August 30, 1996. The northwest and northeast groundwater treatment facilities emissions are remedial actions conducted under CERCLA, and consequently do not have air permits. The total emissions from DOE activities at the Paducah Site in 1997 were too small to require a permit for the entire site in accordance with Title V of the CAA.

DOE submitted a revised air permit application for the Vortec project to KDAQ. The application was revised to reflect the proposed phases of operation for the project. KDAQ has not issued a permit based on the revised application.

Asbestos NESHAP Program

Numerous DOE facilities at the Paducah Site contain asbestos materials. Compliance programs for asbestos management include identification of asbestos materials, monitoring, abatement, and disposal. Procedures and program plans are maintained that delineate scope, roles, and responsibilities for maintaining compliance with the EPA, Occupational Safety and Health Administration, and Kentucky regulatory requirements (no nonconformances with environmental protection standards were identified in 1997). In 1997, the Paducah Site disposed of 204 linear feet of asbestos-containing material resulting from two abatement projects. These projects included maintenance activities in decontamination and decommissioning facilities and waste storage facilities.

Radionuclide NESHAP Program

In 1989, 40 CFR 61 Subpart H was promulgated to regulate airborne radionuclides from DOE facilities. This regulation applies to the Northwest Groundwater Treatment System, which began operation in August 1995, as well as fugitive emissions from Paducah Site DOE facilities such as dust from cylinder yard construction, gravel roads, and the scrapyards. The 1997 NESHAP report will be submitted in June 1998. Ambient air monitoring performed by Utility Services indicates that the combination of DOE and USEC point sources and fugitive emissions are insignificant.

Clean Air Act Amendments of 1990

These amendments are divided into six major titles. The titles that could affect DOE activities at the Paducah Site are Title III, Hazardous Air Pollutants; Title VI, Stratospheric Ozone Protection; and Title V, Permitting.

Title III, Hazardous Air Pollutants

Under the 1990 amendments, Section 112 of the CAA, requirements shifted from a pollutant-by-pollutant, health-based regulatory approach to regulation of categories of sources using technology-based standards. Examples of hazardous air pollutants that must be regulated by the EPA include volatile organic compounds such as benzene and metals such as chromium, cadmium, and manganese. The following summarizes key aspects of this legislation:

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A. Pollutants and Sources Subject to Regulation

The CAA amendments completely overhauled the regulatory approach used for air toxics. Under the new approach, 189 substances are listed by Congress for regulation [Section 112(b)]. Substances can be added to or deleted from the list after rule making, but the EPA need not take any listing action with respect to these 189 substances.

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

B. Maximum Achievable Emission Limitations

For each source category listed for regulation under Section 112, the EPA must promulgate standards requiring the installation of technology that will result in the "maximum degree of reductions" that it determines is "achievable." (This requirement has been referred to as the "maximum achievable control technology" or "MACT" standard.)

C. Residual Risks

Because the MACT standards are technology driven rather than health based, Congress was concerned that health risks could remain even after full implementation of MACT. As a result, the amendments provide for a second phase of regulatory controls aimed at protecting public health with an "ample margin of safety," similar to the pre-1990 Section 112 regulatory standard. This health-based inquiry would generally take place after MACT standards have been implemented for a source category [Section 112(f)].

D. Control of Accidental Releases

Title III requires the EPA to promulgate regulations to control and prevent accidental releases of regulated hazardous pollutants and any other extremely hazardous substance listed by the EPA [Section 112(r)]. Owners and operators of facilities where such substances are present in more than a threshold quantity will have to prepare risk management plans by June 21, 1999 for each substance used at the facility. The Paducah Site does not store or process any of the hazardous pollutants at threshold quantities and does not require a Risk Management Plan. If DOE decides to construct and operate the Vortec project, it would exceed the threshold of 10,000 pounds and, consequently, would require a risk management plan in 1999.

Title IV, Acid Rain

One of the major new regulatory programs of the 1990 amendments concerns control of precursors of acid rain deposition, that is, sulfur dioxide (SO_2) and nitrogen oxides (NO_x). The centerpiece of this program is the establishment of an emissions allowance and trading regime for SO_2 . The Paducah Site has no sources that emit SO_2 or NO_x .

Title V, Permitting

The 1990 CAA amendments created an important new permitting program. Previously, operating permits were not required by federal law, though many state laws provided for such permits. Under Title V of the 1990 amendments, however, the EPA is required to promulgate minimum requirements for state permit programs within one year of enactment [Section 502(b)]. The EPA issued these Title V rules in July 1992.

The Commonwealth of Kentucky applied for authorization to implement the Title V program with the federal EPA and received acceptance in December 1995. As the Paducah Site is not a major source, the KDAQ has agreed that a Title V permit is not required.

Title VI, Stratospheric Ozone Protection

In addition, Title VI of the 1990 amendments incorporates stratospheric ozone protection by restricting the production and consumption of chlorofluorocarbons, halons, methyl chloroform, carbon tetrachloride, and hydrochlorofluorocarbons. Halon, chlorofluorocarbons, methyl chloroform, and carbon tetrachloride have been phased out in DOE operations. The phaseout of hydrochlorofluorocarbons is to be accomplished over a longer period, stretching out to 2020–2040. Finally, the 1992 amendments require that production and consumption of hydrobromofluorocarbons be phased out beginning in 1996 and that methyl bromide be added to the list of controlled substances.

Since DOE has no such refrigeration units that contain more than 50 pounds, the only part of this regulation that applies to the Paducah Site is the requirement to control refrigerants from leaking systems and controls and record keeping at the time of disposal. DOE has implemented these controls and a record-keeping system.

CAA NOVs

On August 28, 1997, DOE received a Notice of Violation from KDAQ for violations of two air permits. DOE failed to notify KDAQ of the start of construction of the Vortec Project and the painting contractor conducting cylinder refurbishment failed to record a gauge reading on two separate days of operation as required by the permit. DOE has revised its preconstruction reporting policy to ensure KDAQ is properly notified, and the cylinder painting contract has been revised to provide additional oversight of permit conditions.

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The second violation was that DOE had begun site preparation but failed to notify KDAQ of the start of construction for the Vortec project. DOE had notified KDEP before site preparation, however, KDAQ required direct notification. DOE has amended its notification protocol to meet these requirements.

Kentucky/DOE Agreement in Principle

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

DOE Order Compliance

The following section has been developed to discuss compliance with those environmental requirements not found in specific statutes or where DOE is primarily self-regulating. The following section provides compliance information for DOE Orders 5400.1, 5400.5, and 5820.2A. These DOE Orders are being followed as guidance documents for complying with the necessary and sufficient process.

DOE Order 5400.1, General Environmental Protection Program

DOE Order 5400.1 establishes environmental protection program requirements, authorities, and responsibilities for DOE operations for assuring compliance with applicable Federal, State and local environmental protection laws and regulations, Executive Orders, and internal DOE policies. The order specifically defines the mandatory environmental protection standards (including those imposed by federal and state statutes), establishes reporting of environmental occurrences and periodic routine reporting of significant environmental protection information, and provides requirements and guidance for environmental monitoring programs.

The internal environmental protection programs mandate the creation of several environmental reports. These reports include the long range environmental protection plan, the annual site environmental report, reports of significant nonroutine releases of hazardous substances, the groundwater protection management plan, the waste minimization program plan, and the pollution prevention awareness plan.

DOE Order 5400.1 also requires an environmental monitoring plan that is to be reviewed annually and updated every three years. The environmental monitoring plan was revised and reissued in December 1997. The environmental monitoring plan defines effluent monitoring and environmental surveillance

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activities for the Paducah Site. Environmental media in pathways significant to the exposure of humans and the environment are included in the monitoring program, specifically, surface water, groundwater, sediment, and biological media.

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

DOE Order 5400.5 provides guidance and establishes radiation protection standards designed to protect the public and the environment against undue risk from operations of DOE and DOE contractors. The order requires that off-site radiation doses not exceed 100 millirem (mrem) per year for all pathways. During 1997, the worst-case estimated dose from Paducah Site (DOE) operations was 1.14 mrem/year, which includes a 1.14 mrem dose from sediments and direct radiation in Little Bayou Creek. Various modeling and dose-calculation activities are conducted to address the potential for multiple-pathway exposures of the public.

The Paducah Site is also well below all applicable media-specific dose limits, such as the EPA limit of 10 mrem/year from airborne emissions and the DOE derived concentration guide for specific radionuclides in surface water discharges. The Paducah Site is in compliance with the requirements of DOE Order 5400.5.

DOE Order 5820.2A, Radioactive Waste Management

DOE Order 5820.2A provides that mixed waste and low-level waste be managed in a manner protective of health, safety, and the environment; minimizes generation; and complies with all applicable regulations and requirements. This order defines the requirements for treatment, storage, and disposal of radiological waste.

Assessments

Paducah Site environmental management programs are overseen by several organizations, both within and outside the DOE complex. Each year, numerous appraisals, audits, and surveillances of various aspects of the environmental compliance program are conducted. Table 2.4 contains a summary of the assessments conducted in 1997.

Table 2.4 Environmental assessments at the Paducah Site in 1997

Date	Auditor	Type
March 17	KDWM	Spot inspection of the EMEF Groundwater Program. Various projects reviewed for past drilling activities, monitoring well installation, and abandonment practices.
March 27	KDOW	Inspection of continuous flow outfalls.
April 22	KDWM	First unannounced inspection of the new C-746-U Solid Waste Contained Landfill, including a review of permit documents and waste operations information.

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May 15	LMES Central Quality	Review of selected projects at EMEF sites for implementation and compliance with ES/ER/TM-88/R1 and EMEF/EM-P2216 data management requirements.
May 20	KDOW	Inspection of KPDES outfalls.
May 22	DNFSB	Review of progress on response to DNFSB Recommendation 95-1, Improved Safety of Cylinders Containing Depleted Uranium.
July 22	KDWM	Inspections of C-733 and C-746-R.
August 7	KDAQ	Cylinder Painting, Vortec, NW Plume, NE Plume, C-746-R.
August 8	CDM Federal Programs	Field Support Laboratory analyses of TC-99 and volatile analyses.
August 21	KDOW	KPDES Outfalls
August 22	KDWM	C-746-K Rip-Rap Placement, Well Abandonment at Lasagna, and Roto-Sonic Drilling at WAG 6.
September 4	KDWM/KDOW	Inspection of the C-746-U Solid Waste Contained Landfill.
September 18	KDWM	Unannounced Annual RCRA Inspection--C-404 Landfill Cap, C-746-Q, C-733, C-722-A, C-409, Manifests and Inspection Records.
October 11	LMES Central	Milestones, Actions, and Commitment Tracking System.
December 12	KDWM	Monitoring Well Installation at the WAG 6 Project at C-400. Included Verification of the Driller's KY Certification Card and Oversight of Installation of the Well Casing and Screen Down the Hole, Setting the Sand Pack, and Placement of the Seal/Plug.

Tiger Team Environmental Assessment

The status of corrective actions resulting from the 1990 DOE Tiger Team assessment for Paducah Site is summarized in Table 2.5.

Table 2.5 Summary of Tiger Team Corrective Actions

	Environmental Findings	Closed Actions	Remaining Open Actions
The only action still open is: Receive approval of the WAG 24 Work Plan by EPA/KDEP.	40 (62 total findings, 40 remained with DOE after lease agreement with USEC)	39	1

Current Issues

Summary of Neighbor Litigation

In January of 1997, a group of PGDP neighbors filed suit against Union Carbide, Martin Marietta Energy Systems, Inc., Lockheed Martin Energy Systems, Inc., Martin Marietta Utility Services, Inc., and Lockheed Martin Utility Services, Inc. alleging personal and property damages resulting from the discharge of hazardous and radioactive constituents from PGDP since commencement of operation in 1952.

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On February 28, 1997, answers were filed by the defendants. Depositions of Plaintiffs were taken in May 1997. Defendants filed Motion for Summary Judgement based on statute of limitations on September 15, 1997. Plaintiffs filed Response and Defendants' filed Reply. Case currently submitted to Court for decision.

Summary of Vortec Litigation

On July 10, 1997, the Department of Energy (DOE) and local environmental activist filed a Joint Stipulation of Dismissal. The lawsuit concerned the categorical exclusion listings in the DOE's 1992 NEPA regulations and the application of one of those exclusions to the proposed Vortec Corporation Vitrification Demonstration project at the PGDP. Additional information about the Vortec project can be found in Section 3.

The Joint Stipulation is based on a Settlement Agreement that commits DOE to withdraw the remaining categorical exclusion determination (DOE withdrew one categorical exclusion determination before the Settlement Agreement) for the proposed Vortec project and to prepare an environmental assessment analyzing the potential environmental impacts associated with the proposed Vortec project. According to the Settlement Agreement, DOE can take delivery of the equipment for the Vortec process, but cannot assemble the equipment or consider procurement of the equipment in its decision whether to proceed with the project.

Pursuant to the Agreement, the court has dismissed the plaintiff's claim against DOE's 1992 and 1996 NEPA regulations. The plaintiff is allowed under the Agreement to file another lawsuit challenging the 1992 and 1996 regulations, but cannot do so in conjunction with the Vortec project.

Resurvey of DOE Reservation Boundary

Dummer Surveying and Engineering Services, Inc., and Barge, Waggoner, Sumner, and Cannon under the direction of Lockheed Martin Energy Systems, Inc., and DOE Real Estate, conducted a survey of the DOE reservation boundary in order to more clearly re-establish property boundaries between DOE and the PGDP's surrounding neighbors. This project involved a land survey of the entire fee-owned boundary of the DOE reservation. Current fee-owned acreage contained with the Paducah Site is 3,422.95 acres. The survey was based on the deeds of acquisition and where disposal occurred on the quitclaim deeds from AEC/DOE to private parties. The boundary survey was completed in accordance with Standards of Practice for Land Surveying in Kentucky, DOE requirements, and American Congress on Surveying and Mapping. The property owners involved in this survey included DOE, WKWMA, TVA, and local residents whose property adjoins DOE property.

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3. Environmental Program Information

Abstract

Environmental monitoring, environmental restoration, waste management, and depleted uranium hexafluoride cylinder management activities occur on-site. Numerous outreach programs are conducted to inform the public about these activities.

Environmental Monitoring Program

The environmental monitoring program at the Paducah Site consists of effluent monitoring and environmental surveillance. Requirements for routine environmental monitoring programs were established to measure and monitor effluents from Department of Energy (DOE) operations and to maintain surveillance on the effects of those operations on the environment and public health through measurement, monitoring, and calculation. The environmental monitoring program is also intended to demonstrate that DOE operations at the Paducah Site comply with DOE orders and applicable federal, state, and local regulations.

Before the DOE/United States Enrichment Corporation (USEC) transition (described in Section 1), DOE's primary mission at the Paducah Site consisted of enriching uranium. However, since the transition on July 1, 1993, DOE's mission at the site has become environmental restoration, depleted uranium hexafluoride cylinder management, and waste management. This change in mission has also changed the direction and emphasis of the environmental monitoring program. In November 1995, the *Environmental Monitoring Plan*, required by DOE Order 5400.1, *General Environmental Protection Program*, was reissued to address DOE operations exclusively.

Environmental Restoration Program

The goal of the Environmental Restoration Program is to ensure that releases from past operations and waste management at the Paducah Site are investigated and that appropriate remedial action is taken for the protection of human health and the environment. In May 1994, the Paducah Gaseous Diffusion Plant was added to the Environmental Protection Agency's (EPA) National Priorities List of the nation's hazardous waste sites that most require cleanup. Two federal laws, Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), are the dominant regulatory drivers for environmental restoration activities at the Paducah Site. RCRA sets the standards for managing hazardous waste and requires permits to be obtained for DOE facilities that treat, store, or dispose of hazardous waste and requires assessment and clean-up of hazardous waste releases at facilities. CERCLA addresses uncontrolled releases of hazardous substances and requires cleanup of inactive waste sites.

Environmental Restoration Program Activities

The Environmental Restoration Program supports remedial investigations, decontamination and decommissioning of facilities no longer in use, projects designed to demonstrate advancements in

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remedial technologies, and related projects in order to take remedial action for the protection of human health and the environment.

Waste Area Groupings

At the Paducah Site, solid waste management units (SWMUs) and areas of concern (AOCs) are surface sources of contamination. To expedite investigations, the SWMUs/AOCs are grouped together into waste area groupings (WAGs) based on certain criteria as follows:

- Common Remedial Technologies
- Common Geographic Locations
- Common Release Mechanisms
- Common Media Type
- Operating Units
- Common Contaminant Sites
- Common Operational Processes
- Common Surface Water Drainage
- Hydraulically-Connected Areas
- Suspected Sources of Off-site Contamination

Some SWMUs/AOCs may be reassigned to other WAGs as a result of new investigations or developments in technology.

The WAGs are investigated as a RCRA facility to collect sufficient information on each SWMU to evaluate the extent of contamination and collect the data necessary to prepare a corrective measures study. The sampling strategy collects information only as needed to make risk-based and corrective action-based decisions. WAGs scheduled for action in the near future are listed in Table 3.1.

Table 3.1 WAG activity during 1997.

WAG	SWMU	Status
1, 7	C-746-K Inactive Sanitary Landfill, Fire Training Area C-740 TCE Spill Site, C-611 1000-gal Diesel/Gasoline Tank C-611 55-gal Gasoline Underground Storage Tank C-611 50-gal Gasoline Underground Storage Tank C-611 2000-gal Oil Underground Storage Tank C-611 Unknown Size, Grouted Underground Storage Tank	<ul style="list-style-type: none">- Received regulatory approval of Proposed Plan 01/97- Issued draft ROD 04/97 and final draft ROD 09/97 to regulators- Submitted D1 Remedial Design 04/97 and received regulatory approval 07/97
3	C-747 Contaminated Burial Ground C-746-F Classified Burial Ground C-747 Burial Area	<ul style="list-style-type: none">- Issued RI/FS Scoping document to regulators 03/97- Completed DQQ process with regulators for RI/FS 06/97
6	C-400 TCE Leak Site C-400 Technetium Storage Tank Area C-400 Basement Sump, C-403 Neutralization Tank C-400 to C-404 Underground Transfer Line	<ul style="list-style-type: none">- Submitted TSPP to regulatory agencies 11/96- Received regulatory approval of TSPP 03/97- Received regulatory approval of RI/FS Work Plan 04/97
9, 11	C-722 Acid Neutralization Tank C-712 Acid Neutralization Lagoon C-616-L Pipeline and Vault Soil Contamination C-729 Acetylene Building Drain Pits C-410-B HF Neutralization Lagoon C-410-E Emergency Holding Pond C-410-C Neutralization Tank	<ul style="list-style-type: none">- Submitted draft Sampling Plan 02/97 and draft final Sampling Plan 06/97 to regulators for an SE

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WAG	SWMU	Status
15	SWMU 24-C-750-D UST SWMU 97-C-601 Diesel Spill SWMU 139-C-746-A1 UST SWMU 140-C-746-A2 UST SWMU 72-C-200-A UST SWMU 73-C-710-B UST	- Submitted SE Report to regulators 12/96 and received NFA approval 07/97
17	36 Different Concrete Rubble Piles	- Submitted WAG 17 Proposed Plan to regulators and received approval 07/97 - Issued signed ROD for NFA 09/97
22	C-747-A Burial Ground, C-747-A Burn Area C-404 Low-Level Radioactive Waste Burial Ground C-749 Uranium Burial Ground	- Completed SWMU 2 Remedial Investigation and submitted RI/Data Summary Report to regulators 02/97 - Completed SWMUs 7&30 Remedial Investigation and submitted RI Report to regulators 07/97
23	C-747-C Oil Landfarm, C-728 Clean Waste-oil Tank C-540-A PCB Waste Staging Area and Spill Site C-541-A PCB Waste Staging Area and Spill Site C-340 PCB Transformer Spill Site, C-611 PCB Spill Site C-728 Motor Cleaning Facility	- Issued EE/CA for PCB-removal action 05/97 - Signed WAG 23 Action Memorandum for removal action 09/97
26	Northwest Plume Northeast Plume	- Submitted NE Plume Containment System O&M Plan to regulators 11/96 and received approval 05/97 - Submitted Annual Report to regulators for NW Plume treatment system 11/96 - Completed construction of NE Plume Containment System 12/96 - Submitted NE Plume Containment System Postconstruction Report to regulators 02/97
27	C-747-C Oil Landfarm C-746-A Septic System	- Submitted D1 RI/FS Work Plan 11/96 and revised Work Plan (D2) 06/97 to the regulators
28	C-745 Kellogg Building Site McGraw UST McGraw Southside Cylinder Yards McGraw Construction Facility (South Side) Dykes Road Historical Staging Area	- Issued RI/FS Scoping document to regulators 12/96 - Completed DQO process for RI/FS with regulators 02/97 - Submitted RI/FS Work Plan to regulators 05/97
Lasagna	UF ₆ Cylinder Drop Test Area	- Completed technology demonstration for in situ TCE remediation at SWMU 91 - Issued SWMU 91 Feasibility Evaluation 07/97 - Submitted SWMU 91 Proposed Plan to regulators 08/97 proposing the "Lasagna Technology" for full-scale implementation

Operable Units

Once a WAG is prioritized and the corresponding Remedial Investigation/Feasibility Study (RI/FS) identifies a specific problem warranting action, a remedy is selected and implemented. The selection and implementation of remedies, which are documented in the Record of Decision (ROD) and Action

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Memorandums, are referred to as operable units (OUs). OUs may address geographic portions of a site, specific site problems, or initial phase of an action. They may also consist of sets of actions performed over time. Integrator units will be investigated and remediated independently from the SWMUs/AOCs because sources of contamination are uncertain and involve several WAGs. Contaminated groundwater is grouped within a groundwater integrator unit. Likewise, contaminated surface water is grouped within a surface water integrator unit.

Groundwater Integrator Unit

The groundwater integrator unit is discussed in Section 9.

Northwest Plume Groundwater System

The Interim Remedial Action of the Northwest Plume Groundwater System was documented in a ROD signed by DOE and the EPA in July 1993. The ROD was concurred with by the Kentucky Department for Environmental Protection (KDEP). The interim remedial action began operations on August 28, 1995. The interim remedial action consists of two extraction well fields of two wells each, transfer pipelines, a treatment system, and appurtenant equipment. The interim action is designed to remove the contaminants of trichloroethylene (TCE) and technetium-99 (^{99}Tc) from groundwater.

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

^{99}Tc is removed by an ion exchange process. During the treatment process the ^{99}Tc in the groundwater is exchanged for a chlorine ion, which is contained in the ion exchange resin held in treatment vessels.

The treatment system has extracted and treated approximately 226 million gallons of contaminated groundwater from start up through the end of 1997. The treatment system has been on-line approximately 97 percent of the time since startup, exceeding the goal of 85 percent. The interim remedial action has consistently met the groundwater treatment goals as documented in the ROD of five parts per billion (ppb) TCE and 900 picocuries per liter (pCi/L) of ^{99}Tc . The groundwater, after treatment, is released through a Kentucky Pollutant Discharge Elimination System (KPDES) permitted outfall. Radiological emissions from this facility are shown in Chapter 4.

Northeast Plume Containment System

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

February 28, 1997. Through the end of 1997, approximately 74 million gallons of contaminated groundwater have been extracted. The system has remained operational approximately 92 percent of the time since startup.

System operation includes pumping water contaminated with TCE from two extraction wells to an equalization tank. A transfer pump is used to pump the contaminated water from the equalization tank through a transfer line (greater than 6,000 linear feet) to the top of the C-637 Cooling Tower. The cooling tower acts as an air stripper and removes the TCE from the groundwater. The Northeast Plume does not contain ^{99}Tc .

Decontamination and Decommissioning

Decontamination and decommissioning is the disposition of facilities and other structures contaminated with radiological and hazardous material. Facilities are accepted for decontamination and decommissioning when they are no longer required to fulfill a site mission. Legacy contamination on the structure, floors, walls, and equipment constitutes a potential for release to the environment if not appropriately managed in the near term and ultimately removed. Two major facilities comprising approximately 46,450 m² (500,000 ft²) have been accepted for decontamination and decommissioning. These facilities are the C-340 metal reduction plant complex, where uranium hexafluoride (UF₆) was converted to uranium metal and hydrogen fluoride, and the C-410 feed plant complex, where uranium trioxide (UO₃) was converted to UF₆. Major contaminants at these facilities include depleted uranium, normal uranium (at C-410 only), uranium tetrafluoride, polychlorinated biphenyls (PCB), asbestos, and lead paint. Activities performed during the year include surveillance and maintenance of the structures to ensure containment of residual materials, decontamination and decommissioning project planning for future implementation and planning, and implementation for the removal/sale of surplus equipment to private industry.

Technological Demonstration

The Environmental Restoration Program actively supports demonstrating new remediation technologies that have been developed by private industry. These demonstrations serve as advanced "field tests" for the companies' products. A demonstration was performed for the technology, Lasagna®. This technology demonstration is discussed in more detail in Section 9.

Two demonstrations were conducted at the Northwest Plume Groundwater System (NWPGS) involving possible improved methods for removal of ^{99}Tc from the groundwater. The 3M Company provided a test system equipped with a new, coated micropore filter designed to remove ^{99}Tc . The filters, configured in an easily removable cartridge arrangement, were tested on a groundwater side stream in the NWPGS C-612 building. Results indicated a ^{99}Tc removal capacity similar to the ion exchange resin currently in use. At the time of the tests, however, the resins were not available in a size that would meet the flow requirements of the NWPGS. A second test was conducted on a new synthetic ion exchange resin developed by scientists at Oak Ridge National Laboratory. The resin is similar in function and physical characteristics to the commercial resin currently used for ^{99}Tc removal at the NWPGS C-612. Preliminary laboratory studies of the synthetic resin indicated ^{99}Tc removal efficiencies in excess of five times that of the commercial resin. Results from a small test column placed in the NWPGS C-612

facility confirmed the laboratory test results. If the synthetic resin can be manufactured in quantities and at prices meeting the NWPGS needs, its use could result in a reduction of waste for the project.

Waste Management Program

The Paducah Site Waste Management Program directs the safe storage, treatment, and disposal of waste generated before July 1, 1993 (i.e., "legacy" wastes), and waste from current DOE activities. The primary objective of the program is to ensure that waste materials do not migrate into the environment. Waste managed under the program is divided into eight categories: low-level radioactive, hazardous, mixed, transuranic, PCB, PCB contaminated, asbestos, and conventional sanitary waste.

- *Low-level radioactive waste* - radioactive waste not classified as high-level or transuranic and that does not contain any components regulated by RCRA or Toxic Substances Control Act (TSCA).
- *Hazardous waste* - waste that contains one or more of the wastes listed under RCRA or that exhibits one or more of the four RCRA hazardous characteristics: ignitability, corrosivity, reactivity, and toxicity.
- *Mixed waste* - waste containing both hazardous and radioactive components. Mixed waste is subject to RCRA, which governs the hazardous components, and to additional regulations that govern the radioactive components.
- *Transuranic waste* - waste that contains more than 100 nanocuries of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years.
- *PCB and PCB-radioactive wastes* - waste containing PCBs, a class of synthetic organic chemicals including 209 known isomers, each with from 1 to 10 chlorine atoms on a biphenyl ring. Under TSCA regulations, PCB manufacturing was prohibited after 1978. However, continued use of PCBs is allowed provided that the use does not pose a risk to human health or the environment. Disposal of all PCB materials is regulated.
- *Asbestos waste* - asbestos-containing materials from renovation and demolition activities.
- *Sanitary waste* - waste that is neither radioactive nor hazardous. Solid sanitary waste is basically refuse and is disposed in landfills.

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

Compliance for waste management activities involves meeting EPA and state regulations and DOE orders. In addition to compliance with these regulations, supplemental policies are enacted for management of radioactive, hazardous, and mixed wastes. These policies include reducing the amount of wastes generated; characterizing and certifying waste before it is stored, processed, treated, or disposed; and pursuing volume reduction and use of on-site storage, when safe and cost effective, until a final disposal option is identified. Table 3.2 summarizes the major accomplishments of the Waste Management organization during 1997.

Table 3.2 Waste Management Accomplishments during 1997

Characterized approximately 3,000 drums of waste for the Vortec Demonstration

Issued first draft of Vortec Air Permit modification

Completed the 44 Sampling and Analyses Plans, meeting an EPA milestone three months ahead of schedule and TCLP characterization of 780 containers (cumulative total 25% complete) as required by the TCLP FFCA

Completed 22 characterization events (70% of LDR inventory) for the LDR FFCA/FFC Act-STP

Disposed over 4,700 tons of USEC and DOE waste in the C-746-U landfill which included approximately 600m³ (5% of current inventory of containerized waste)(operated only 11 months)

Completed off-site treatment/disposal of 30 m³ (~4% of RCRA inventory) of RCRA waste

Completed off-site shipments of 165m³ (328,000 pounds) (~3% of RCRA/PCB inventory) of liquid RCRA/PCB waste to the ETTP (formerly K-25) TSCA incinerator

Treated onsite 49 m³ (104,000 pounds) TSCA/RCRA wastewater

Completed treatment of 36 containers of highly radioactive nitric acid waste

Achieved 13.2% reduction in waste storage areas

Completed upgrades and consolidated all DOE fissile waste in the C-746-Q Fissile Material Storage Area

Initiated operations of a new storage facility, C-752-A RCRA Storage Facility

Issued draft Volumetric Package Report for review, that will lift the DOE shipping moratorium for the Paducah Site

Completed the fifth consecutive RCRA inspection without any notice of violations

Issued draft Study of Metals Reclamation and Associated Site Remediation for the Paducah Site

Issued draft and presented overview of the Off-Site Shipment Management Review Process Guide for the Paducah Site

Completed the cleaning and relocation of approximately 4,000 aluminum ingots.

Completed all regulatory milestones as scheduled

Initiated the development and implementation of an improved Waste Information Tracking Systems

Waste Minimization Program

The Waste Minimization/Pollution Prevention (WMin/PP) Program at the Paducah Site provides guidance and objectives for minimizing solid and hazardous waste generation. Guidance for the program comes from regulations promulgated by RCRA, the Pollution Prevention Act, applicable state and EPA rules, and DOE and executive orders. The Pollution Prevention program also sponsors the Earth Day activities and provided an informational stop during 1997, see Figure 3.1.

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

- source reduction,
- reuse of materials, and
- recycling.

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The WMIn/PP Program has the following objectives:

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

The WMIn/PP Program is administered by the Waste Minimization/Pollution Prevention Program Coordinator, who is part of Environmental Compliance. Record keeping and reporting information is obtained through Site Operations.

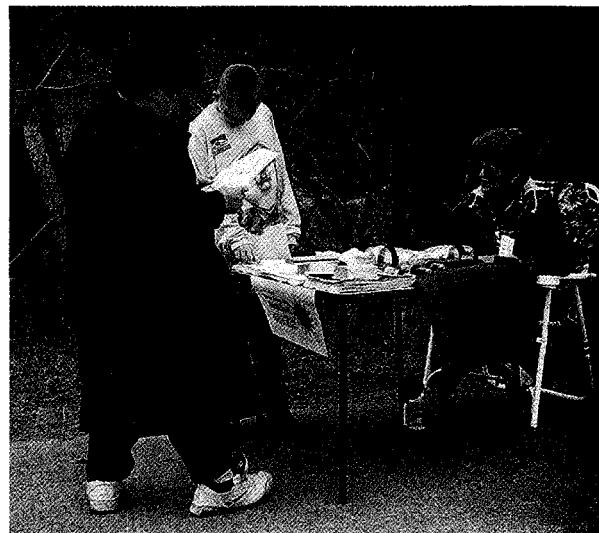


Figure 3.1 Pollution Prevention Activities During Earth Day

In conjunction with Environmental Compliance and Site Operations, the Waste Minimization/Pollution Prevention Program Coordinator identifies waste streams that are high-priority minimization or reduction candidates based on the following factors:

- availability of storage space,
- waste stream hazard,
- availability of treatment and disposal facilities (both on- and off-site),
- regulatory compliance issues, and
- management and disposal costs.

Program Results

Recycling efforts, in 1997, included 12,890 pounds white office paper, and 307 pounds aluminum cans. Other initiatives included continuing the Pilot Generator Set-Aside Fee Program that taxes waste generators for waste generated during projects. Additional accomplishments include: applying waste minimization techniques to well development projects resulting in reductions to wastewater and solid waste; and, incorporating micropurging techniques into groundwater sampling resulting in wastewater reductions.

Vortec Vitrification Technology Demonstration

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

During 1996, activities proceeded toward siting the vitrification facility at Paducah. DOE and Vortec obtained an air permit from the Commonwealth of Kentucky and submitted a RCRA Research, Development, and Demonstration (RD&D) permit application. DOE promulgated a categorical exclusion (CX) to satisfy the requirements of NEPA and held numerous opportunities for public involvement concerning the project. Vortec began preparing a suitable site for erecting the facility. Grading work, piles installation and layout were accomplished during the year. Additionally, Paducah performed the installation of water and power lines to the site. Paducah undertook the characterization of waste streams with potential for treatment by the vitrification facility. Work also progressed during 1996 in the development of health and safety and operational documentation related to the construction of the facility.

During 1997, Vortec continued with site preparation work and DOE continued working toward acquiring a RCRA RD&D permit. Toward that end, the Commonwealth hosted a public hearing to accept stakeholder comments on the permit. Characterization of waste streams with potential for treatment by the vitrification facility also continued during 1997, as did the tasks associated with health and safety and the anticipated operational phase. Additionally, revisions to the air permit were made during the year. The NEPA CX was challenged in a lawsuit by a local stakeholder, and in answer DOE committed to performing an environmental assessment. Work on the environmental assessment began in the last quarter of the year and will continue into 1998.

Depleted Uranium Hexafluoride Cylinder Program

During the development and operation of the enrichment process, containers, support equipment, and support facilities were designed, constructed, and used as a system to store, transport, and process the depleted UF₆ (DUF₆). Solid DUF₆ was stored in large metal cylinders. After a significant inventory was produced, outdoor storage facilities ("cylinder yards") evolved independently at the sites. Cylinder yards are constructed of either concrete, compacted gravel, or asphalt over gravel. The handling equipment used to stack these cylinders has also evolved, from mobile cranes to specifically designed machines that grasp and lift the cylinder with hydraulic controlled tines.

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

The congressional adjustment of DOE's mission from uranium enrichment to uranium inventory management (storage and utilization) has transformed the previous management plan from design, construction, and operation phases to a storage or standby phase. The Program Management Plan for which DOE is responsible has been realigned to containment and use of a finite inventory of DUF₆. The various types of construction and the subsequent deterioration of the yards have led to substandard storage conditions for many of the cylinders. The variety of cylinder designs that have evolved over the years and various paint systems used has resulted in varying corrosion rates. These two main factors led to the need for long term corrosion monitoring of the cylinders.

Potential risks to people and the environment posed by DUF₆ storage as it is managed are low. The DUF₆ is stored as a crystalline solid. When DUF₆ is exposed to the atmosphere, hydrogen fluoride and uranium

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reaction products form. The uranium by-products form a hard crystalline solid, which acts as a self-sealant within the storage cylinder. The hazard potential of the DUF₆ is primarily chemical toxicity from any released hydrogen fluoride, rather than a radiological hazard.

After visiting the DOE sites (Paducah, Portsmouth, and K-25 (currently identified as ETTP)) in 1994 and 1995, the Defense Nuclear Facilities Safety Board (DNFSB) issued Recommendation 95-1 and a supporting technical report. That report addressed the improved safety of cylinders containing DUF₆. DNFSB "Recommendation 95-1 on Depleted Uranium" recommended the following:

- Start an early program to renew the protective coating of cylinders containing the DUF₆ from the historical production of enriched uranium.
- Explore the possibility of additional measures to protect these cylinders from the damaging effects of exposure to the elements, as well as any additional handling that may occur.
- Institute a study to determine whether a more suitable chemical form should be selected for long-term storage of the depleted uranium.

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

- Removing cylinders from ground contact and keeping cylinders from further ground contact;
- Relocating all cylinders into an adequate inspection configuration (this effort continued in 1997 as new storage yards were constructed or as old yards were reconstructed);
- Repainting cylinders as needed to avoid excessive corrosion (783 cylinders were repainted in 1997 and a plan has been developed to recoat 6800 cylinders at the Paducah Site over the next 5 years);
- Updating handling and inspection procedures and site-specific Safety Analysis Reports; and
- Completing an ongoing study that will include an analysis of alternative chemical forms for the material (DOE PEIS).

On October 16, 1995, DOE submitted an Implementation Plan that incorporated complete and near-term actions in accordance with these five focus areas. The Implementation Plan also committed to managing the DUF₆ Cylinder Program using a Systems Engineering Approach. The approach was developed concurrent with field response actions and is enhanced through an open dialogue between DNFSB staff and DOE and Energy Systems personnel. The Implementation Plan specifies the following interim and final deliverables and defines their respective content to establish an operative Systems Engineering process for the continued improvement of DUF₆ management:

- System Requirement Document - identifies the system requirements;
- System Engineering Management Plan - identifies organization, direction, and controls for system integration;
- Engineering Development Plan - identifies development actions, costs, and schedules for technical improvements;
- DUF₆ Cylinder Program Management Plan - identifies costs, schedules, and controls for operating the system and implementing required actions; and
- Approved Safety Analysis Reports - defines the safety envelope.

The system includes several operational functions to maintain containment of the DUF₆. These operational functions are:

- Surveillance and Maintenance,
- Handling and Stacking,
- Contents Transfer, and
- Off-site Transport

DOE is upgrading the quality of the cylinder yards to help maintain the integrity of the cylinders. The C-745-G cylinder yard was reconstructed in 1996 and covers 371,000 square feet. Fewer cylinders will be stored in the refurbished yards resulting in easier access for inspections to detect corrosion on the cylinders. For this reason, DOE initiated construction of a new 470,000 square feet cylinder yard C-745-T which will be completed during the spring of 1998. The design for reconstruction of five more existing storage yards was completed.

Technical Information Exchange

Paducah Site representatives attend both DOE-sponsored and independent information exchange workshops such as the annual DOE Model Conference, quarterly multiplant task team meetings, and professional conferences.

Public Awareness Program

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

Fact Sheets and Public Briefings

During 1997, fact sheets on several topics, including the DOE Accelerated Cleanup Plan and Waste Area Group 22 were published and distributed to stakeholders during public meetings.

A total of four public meetings and two news conferences were held during 1997. Some of the meetings were general in nature, covering a wide range of environmental restoration and waste management topics, while others dealt with specific issues.

Community/Educational Outreach

DOE and Energy Systems Public Affairs sponsored 16 separate educational and community outreach activities during 1997, involving about 50 employees in working with area schools and civic groups. Five facility tours were also conducted.

Earth Day

DOE, Energy Systems, and the Kentucky Division of Fish and Wildlife Resources jointly sponsored, planned and implemented the 1997 Earth Day activities. The two-day event involved about 1,000 sixth-grade students from area school systems. A wide variety of environmental educational programs were available using both the West Kentucky Wildlife Management Area and DOE property. Many of the activities were hands-on, in which the students made decisions and took actions regarding hypothetical environmental problems, see Figure 3.2.



Figure 3.2 Earth Day Activities

Site Specific Advisory Board

The Paducah Site Specific Advisory Board completed its first full year of operation in September of 1997. The board advised and made recommendations to DOE on several projects and issues, and commented on a number of documents released during the period. There were a number of membership changes during the year. In 1997, the board had 15 voting members, with five ex-officios. The board, formed under the Federal Advisory Committees Act, received its charter in August 1996, and consists of individuals with diverse backgrounds and interests. The SSAB meets monthly to focus on early citizen participation on issues regarding cleanup and related environmental decisions at the DOE facility. The board will study only the activities which are governed by DOE and regulated by the Kentucky Department of Environmental Protection (KDEP) and the Environmental Protection Agency (EPA) Region IV.

Environmental Information Center

The public has access to the Administrative Record and programmatic documents at the U.S. DOE Environmental Information Center in the West Kentucky Technology Park in Kevil, Kentucky. The center's hours are 7:30 a.m. to 4:30 p.m. weekdays or by appointment. In addition, documents for public comment are placed in the Paducah Public Library, 555 Washington Street, Paducah, Kentucky. The library is open from 9:00 a.m. to 9:00 p.m. Monday through Thursday, 9:00a.m. to 6:00 p.m. Friday and Saturday, and 1:00 p.m. to 6:00 p.m. on Sunday.

4. Radiological Effluent Monitoring

Radiological liquid effluent monitoring was performed at the five outfalls under the jurisdiction of DOE at the Paducah Site during 1997. Three of the five outfalls retained by DOE contain only rainfall runoff. In addition, one continuous flow outfall is considered the responsibility of DOE. One final outfall is comprised of rain runoff from DOE's contained landfill. The landfill has never received any material contaminated with radioactivity from plant processes and therefore was not part of the radiological monitoring program for DOE. The four other outfalls were monitored for radionuclides historically present at the site. Concentrations of the radionuclides measured (uranium and technetium) for DOE outfalls were within acceptable limits set by DOE and by state and federal standards. The only DOE operated point source for radionuclides in airborne effluents during 1997 was the Northwest Plume Groundwater System.

Introduction

Monitoring of radioactivity in liquid effluents is described in the Paducah Site *Environmental Monitoring Plan* (LMES 1995). Sampling and analytical activities were the responsibility of Lockheed Martin Energy Systems (Energy Systems), but these services were procured from Lockheed Martin Utility Services (Utility Services). The Environmental Monitoring Section, part of the Utility Services Environmental and Waste Management Division, provided sampling support; and the analytical laboratory, part of the Utility Services Production Support Division, provided analytical measurements. Effluents are monitored for radionuclides known to be emitted or to have been present at the site. Dose calculations and comparisons are discussed in Section 6. Applicable regulations are discussed in sections on airborne and liquid effluents.

Airborne Effluents

As a result of the formation of United States Enrichment Corporation (USEC) in 1993, the Department of Energy (DOE) leased the enrichment operations facilities at the Paducah Gaseous Diffusion Plant (PGDP) to USEC. In this lease, USEC assumed responsibility for all existing radionuclide point-source discharges. A small number of fugitive emission sources, such as roads and scrap metal piles, that could act as radionuclide emission sources were retained by DOE. On August 28, 1995, DOE began operation of its only radionuclide point source, the Northwest Plume Groundwater System. The facility is located at the northwest corner of the PGDP security area. The facility consists of an air stripper to remove volatile organics from water and an ion exchange unit for the removal of technetium-99 (^{99}Tc). The air stripper is located upstream of the ion exchange unit. Emissions of ^{99}Tc were estimated using the analysis of the influent groundwater and the water leaving the air stripper. The ^{99}Tc concentration in the influent and effluent of the air stripper and the quantity of the water passing through the stripper were used to estimate the total quantity of ^{99}Tc emitted from the facility. In 1997, the Northwest Plume Groundwater System's ^{99}Tc air emissions were calculated to be 0.003 curies or 0.178 grams.

Applicable Regulations

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

Per 40 CFR 61 Subpart H, DOE must report radionuclide emissions by June 30th of each year to the EPA via a National Emission Standards for Hazardous Air Pollutants (NESHAP) Report. The EPA-approved methodologies for sampling and calculations must be used to address effluents. Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a Record of Decision (ROD) was signed July 22, 1993, for the Northwest Plume Groundwater System. Although under CERCLA, administrative requirements are not required, DOE has continued to supply all related permitting and reporting documentation to regulators as prior to the Paducah Site being listed on the National Priorities List (NPL). The Operations and Maintenance Plan approved by the EPA in March 1995, described sampling and methodologies to be used at the Northwest Plume Groundwater System. The sampling protocol has been used to develop a mass balance differential to quantify the radionuclide stack effluent from the facility. The analysis of the water before and after the air stripper stack provides a much more accurate measure of airborne discharges than actual stack measurements due to the low, practically immeasurable radionuclide airborne effluents associated with the facility.

Airborne Effluent Results

In preparing the Annual 1997 NESHAP Report that summarizes the airborne radionuclide emissions from the entire site, a mass balance from the Northwest Plume Groundwater System air stripper was used to calculate the total curies of radionuclide emissions from the operation. In 1997, releases to the atmosphere are calculated to be 3×10^{-3} (0.003) curies. NESHAP modeling indicates an off-site dose to the maximally exposed individual of 6.2×10^{-4} (0.00062) mrem effective dose equivalent. The collective effective dose equivalent (person-rem/yr) within a 50 mile radius was 2.6×10^{-3} (0.0026).

Liquid Effluents

In addition to radiological parameters on the Kentucky Pollutant Discharge Elimination System (KPDES) permit, specific radionuclide analysis and indicator gross activity analyses are conducted on liquid effluent samples. Grab samples and composite samples at various frequencies are used to measure discharges, see Figure 4.1. DOE was responsible for a total of five outfalls in 1997. Under KPDES permit number KY0004049, Outfall 001 was a continuous flow outfall that receives discharges from the USEC's Phosphate Reduction Facility, USEC's once through cooling water, DOE's Northwest Plume

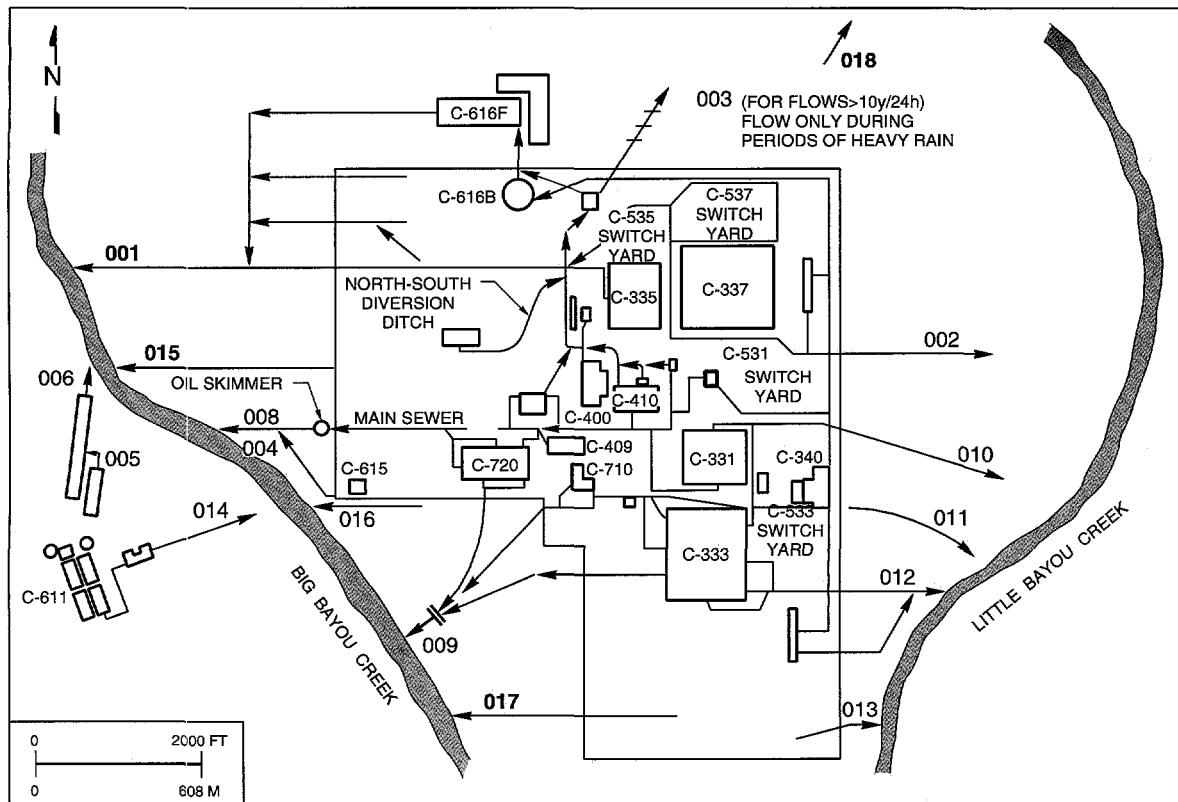


Figure 4.1 KPDES outfall locations at the Paducah Site.
Outfalls 001, 015, 017, and 018 are the responsibility of DOE.

Groundwater System and Northeast Plume Containment System. In addition, surface water runoff from the northeast side of the plant also discharges into outfall 001. 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 yards). Outfall 018 receives surface water runoff from the closed DOE landfills, C-746 S & T. Under KPDES permit number KY0100072, Outfall 001 received surface water runoff from the C-746-U (DOE's operational landfill).

Applicable Regulations

DOE Orders 5400.1 and 5400.5 and the regulatory guide define effluent monitoring requirements to provide confidence that limits are not exceeded. Although no specific effluent limits for radiological parameters are included on the KPDES permit, DOE Order 5400.5 sets guidelines for allowable concentrations of radionuclides in various effluents and requires radiological monitoring to protect public health. This protection is achieved at the Paducah Site by meeting the DOE Order 5400.5 derived concentration guide (DCGs), which are the concentrations of given radionuclides that would result in an effective dose equivalent of 100 mrem/year. The guide is based on the assumption that a member of the public has continuous, direct access to the liquid effluents and consumes 2 liters (0.53 gallon) of effluent every day, 365 days/year, which is a conservative exposure scenario not likely to exist. The EPA safe drinking water limits do not apply to Paducah Site surface water sampling as effluent ditches and Big and Little Bayou Creeks are not drinking water sources for public or private use.

Paducah Site

Liquid Effluent Monitoring Program

Sample Collection Systems

For monitoring purposes, the Paducah Site uses estimates of DCG levels and outfall flow characteristics (rainfall dependant) to determine sampling frequencies. Although the Paducah Site monitors for other radionuclides [neptunium-237 (^{237}Np), plutonium-239 (^{239}Pu), and thorium-230 (^{230}Th)], uranium, and technetium-99 (^{99}Tc) are the primary radionuclides of concern. Neither continuous monitoring nor continuous sampling is required because the sum of fractions of the observed concentration of each radionuclide to its corresponding DCG was much less than 1.0, as described in DOE Order 5400.5. However, quarterly analyses are performed at outfall locations for ^{237}Np , ^{239}Pu , ^{230}Th , dissolved alpha, suspended alpha, dissolved beta, and suspended beta activity.

Surface runoff from both the closed C-746-S residential landfill and the C-746-T inert landfill is monitored quarterly. A grab sample of the landfill runoff is monitored for uranium, gross alpha, and gross beta. The samples are taken from the landfill runoff, upstream of the runoff discharge, and downstream of the discharge at KPDES outfall 018. Sampling is performed to comply with the Kentucky Division of Waste Management permit 073.14 requirements for landfill operations. The landfills will continue to be monitored for 30 years from the date of closure.

Liquid Effluent Monitoring Results

Tables 4.1 and 4.2 give the yearly maximum, minimum, and average concentrations of uranium and technetium, respectively, at each monitoring location. Each radionuclide is compared with the DCG and is presented as a percentage of that standard. The average concentrations at all outfalls were small percentages of the corresponding DCGs for ^{99}Tc .

Table 4.1 Uranium Concentration in DOE Outfalls for 1997

Outfall ^a	No. Of Samples	Concentration (mg/L)			(pCi/L) ^b	wt % ^{235}U Av.	Percentage of DCG ^c
		Max	Min	Av.			
K001	94	0.072	0.001	0.016	8.1	0.45	1.4
K015	11	0.57	0.012	0.176	75.3	0.30	12.6
K017	2	0.009	0.001	0.005	2.9	0.55 ^d	0.5
K018	3	0.022	0.009	0.017	9.5	0.53	1.6

^a See Figure 4.1

^b 1 pCi/L = 0.037 Bq/L

^c DCG for uranium is 600 pCi/L

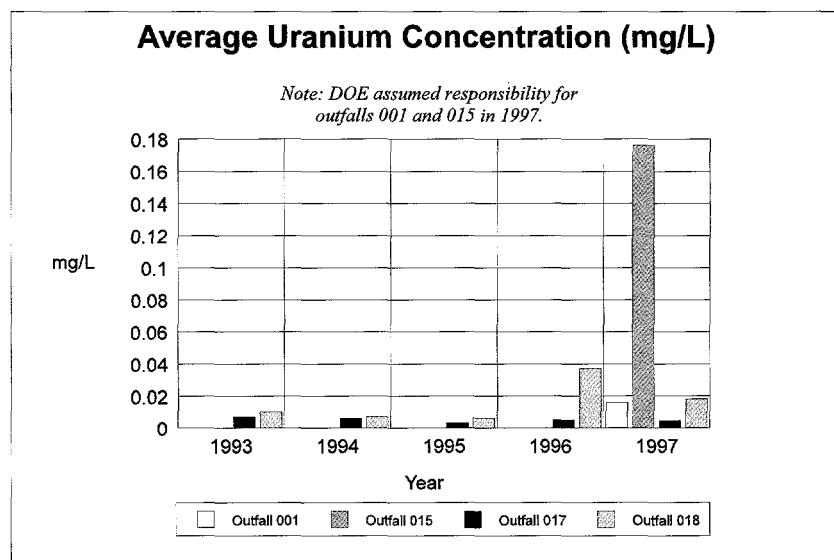
^d Insufficient uranium quantities to analyze for assay, assay based on past data

Table 4.2 ^{99}Tc Concentration in DOE Outfalls for 1997

Outfall ^a	No. Of Samples	Concentration (pCi/L) ^b			Percentage of DCG ^c
		Max	Min	Av.	
K001	14	34	0	12	0.012
K015	11	53	6	20	0.020
K017	2	2	0	1	0.001
K018	10	57	0	23.81	0.024

^a See Figure 4.1^b 1 pCi/L = 0.037 Bq/L^c DCG for ^{99}Tc is 100,000 pCi/L

Technetium averages for 1997 did not approach 1% of the 100,000 picocuries per liter (pCi/L) DCG. Data for 1997 do not show a significant change in relation to DCG levels for either radionuclide compared to 1996 data. The historical trends of yearly average uranium and ^{99}Tc concentrations in outfalls 017 and 018 are shown in Figures 4.2 and 4.3. In 1997, DOE accepted responsibility for outfalls 001 and 015 which have been added to Figure 4.2 for 1997. While the uranium discharge from outfall 015 was higher than what has been seen in other DOE outfalls, the level is consistent with historic concentrations identified at this location.

**Figure 4.2 Uranium concentrations discharged to surface water, 1993 - 1997.**

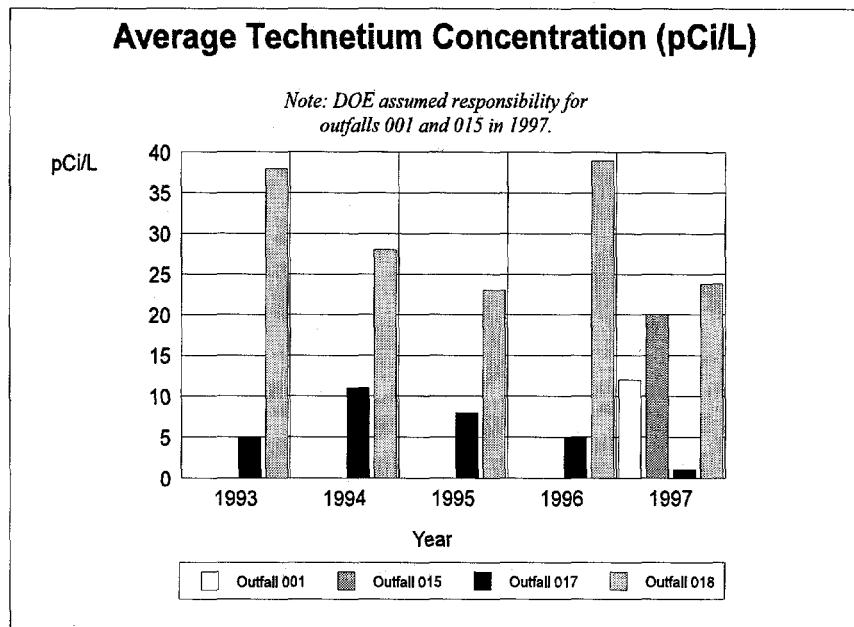


Figure 4.3 Technetium concentrations discharged to surface water, 1993 - 1997.

During 1997, responsibility for outfalls 001 and 015 were transferred to DOE. Outfall 015 receives runoff from the uranium burial grounds with small quantities of surface contamination from uranium compounds. The average concentration of uranium discharging as a result of runoff from the burial grounds was 12.6% of the DCG. Outfalls 001, 017, and 018 were less than 2% of the DCG.

5. Radiological Environmental Surveillance

Abstract

The purpose of the radiological environmental surveillance program is to assess the effects of the Department of Energy activities on the surrounding population and environment. Surveillance includes analysis of surface water, groundwater (see Section 9), sediment, and terrestrial wildlife. Surveillance results indicated that radionuclide concentrations in sampled media were within applicable standards. Direct radiation is also measured (see Section 6).

Introduction

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

As a result of the formation of United States Enrichment Corporation (USEC), DOE leased the operating sections of the Paducah Gaseous Diffusion Plant (PGDP) to USEC. DOE retained responsibility for locations where historic contamination might exist and liability for any existing contamination or problems. During 1997, outfalls 001 and 015 were transferred to DOE from USEC because of historical contaminants. Per the lease, USEC is responsible for the existing radionuclide point-source discharges, with the exception of the Northwest Plume Groundwater System. A small number of fugitive emission sources, such as roads and scrap metal piles, that may act as fugitive radionuclide air emission sources were retained by DOE.

Ambient Air

DOE facilities do not have sufficient radioactive emissions to warrant an ambient air surveillance system. However, USEC maintains and operates an ambient air monitoring system to assess the impact of radioactive particulates emitted from the plant site on the surrounding environment and population.

Meteorological Monitoring

DOE Order 5400.1 requires that DOE facilities collect representative meteorological data in support of environmental monitoring activities. This information is essential to characterize atmospheric transport and diffusion conditions in the vicinity of the Paducah Site and to represent other meteorological conditions (e.g., precipitation, temperature, and atmospheric moisture) that are important to environmental surveillance activities such as air quality and radiation monitoring.

Paducah Site

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

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

Surface Water

All Paducah Site effluents are released either to the west to Big Bayou Creek or to the east to Little Bayou Creek via plant outfalls. The net impact of the Paducah Site on surface waters can be evaluated by comparing data from samples collected upstream of the site with sample information collected downstream of the site. Water from Big and Little Bayou Creeks are designated for all uses by the Commonwealth of Kentucky and are considered to be waters of the Commonwealth. Discharges of effluents other than radioactive effluents from the site are controlled under KPDES. Radioactive effluents are controlled via DOE Order 5400.5.

Monthly sampling is conducted at upstream Big Bayou Creek (SW 1), downstream Big Bayou Creek (SW 5), downstream Little Bayou Creek (SW 10), upstream Ohio River (SW 29), and downstream Ohio River (SW 30). No sample point exists for upstream Little Bayou Creek. The watershed is insufficient to develop adequate flow to monitor. Most of water in Little Bayou Creek is comprised of discharges from plant outfalls. Background water quality is sampled at Big Bayou location SW 1. Figure 5.1 depicts sampling locations. Table 5.1 shows all analyses and frequencies for radiological surveillance.

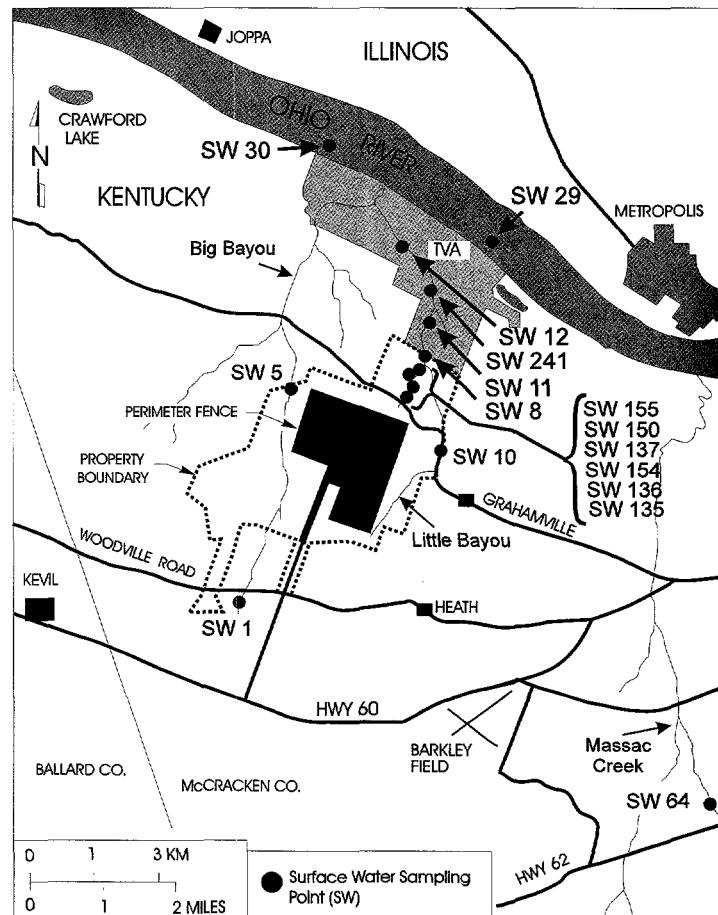


Figure 5.1 Surface water monitoring locations at the Paducah Site.

Surface Water Surveillance Results

Table 5.2 reflects the average concentration of radionuclides present upstream and downstream of plant effluents in Big Bayou Creek and downstream of plant effluents in Little Bayou Creek. Comparisons can be made to determine the influence of plant effluents. Little Bayou Creek upstream of plant effluents has insufficient flow to take samples most of the year. The background or reference site for Little Bayou Creek monitoring is upstream Big Bayou Creek (SW1). Big and

Little Bayou combine north of the site and discharge into the Ohio River. Monitoring results in Table 5.2 also show average Ohio River radionuclide concentrations upstream of the confluence with Bayou Creeks and downstream of the confluence. Upstream and downstream results can be compared to look at the effect of site discharges on the Ohio River.

Comparison of upstream Big Bayou Creek (SW1) with downstream Big and Little Bayou Creek locations shows a slight increase in technetium and uranium. Concentrations over background (SW1) are insignificant. When comparing upstream and downstream samples in the Ohio River, an increase in uranium and thorium-230 is seen, while technetium-99, plutonium-239, and neptunium-237 show a decrease. The concentrations that are greater than background, are not considered significant.

Table 5.1 Sampling parameters and collection and analysis frequencies of surface water at the Paducah Site for 1997

Station ^a	Parameter	Collection Frequency	Sample Type	Analysis Frequency
SW1, SW5, SW10, SW11, SW29, SW64	Dissolved alpha and beta, suspended alpha and beta, ²³⁷ Np, ²³⁹ Pu, ⁹⁹ Tc, U, % ²³⁵ U, ²³⁵ U, ²³⁸ U, ²³⁰ Th, Gross Gamma	Bi-monthly	Grab	Bi-monthly
SW8	⁹⁹ Tc	Semi-annually	Grab	Semi-annually

^a See Figure 5.1

Table 5.2 Radiological Surface Water Surveillance Results

Analysis	SW10 Down Stream Little Bayou	SW1 Upstream Big Bayou	SW5 Downstream Big Bayou	SW29 Upstream Ohio River	SW30 Downstream Ohio River
Uranium (mg/L)	0.008	0	0.005	0	0.001
⁹⁹ Tc (pCi/L)	9.429	4.143	12.857	3.429	3.167
²³⁷ Np (pCi/L)	0.129	0.157	0.086	0.157	0
²³⁹ Pu (pCi/L)	0	0	0	0.004	0
²³⁰ Th (pCi/L)	0	0	0	0	0.065

Sediment

Sediment is an important constituent of the aquatic environment. If a pollutant is a suspended solid or is attached to suspended sediment, it can settle to the bottom (thus creating the need for sediment sampling), be taken up by certain organisms, or become attached to plant surfaces.

Pollutants in solution can adsorb on suspended organic and inorganic solids or be assimilated by plants and animals. The suspended solids, dead biota, or excreta settle to the bottom and become part of the organic substrata that support the bottom-dwelling community of organisms. Figure 5.2 shows possible exposure routes of trace metals (including uranium) in an aquatic ecosystem (Jinks and Eisenbud 1972).

Sediments play a significant role in aquatic ecology by serving as a repository for radioactive or chemical substances that pass via bottom-feeding biota to the higher trophic levels. Soluble pollutants introduced into a body of water reach the bottom sediment primarily by adsorption on suspended solids that later deposit on the bottom. The deposited remains of biota that have absorbed pollutants may also be an important source of radioactive pollutants that enter the food chain.

Sediment Surveillance Program

Because DOE retained responsibility for historic environmental issues and problems, ditch sediments are tracked through a radiological environmental surveillance program. Sediment samples were taken from six locations, see Figure 5.3. Table 5.3 lists the monitoring parameters and the collection and analysis frequencies for sediment samples.

Sediment Surveillance Results

Table 5.4 shows the 1997 results for sediment sampling. Locations SS1, SS2, and SS27 are downstream of plant effluents and may be impacted by discharges. Locations SS20, SS21, and SS28 are considered

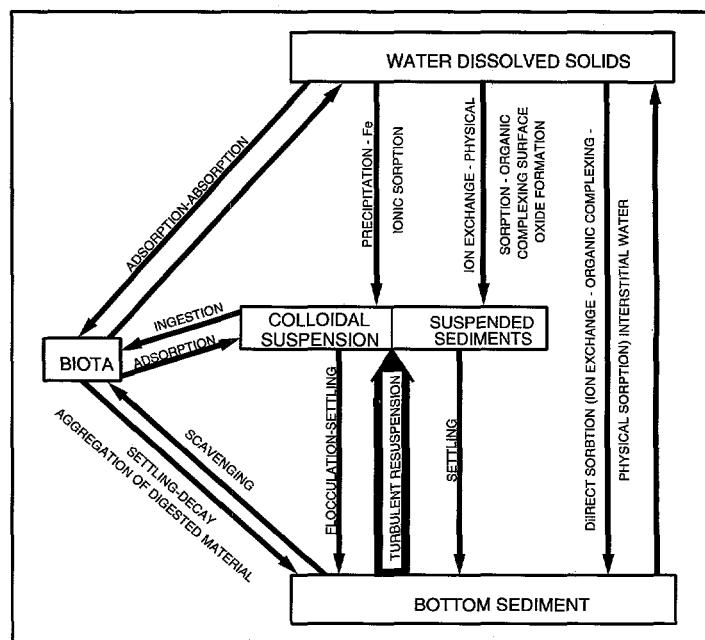


Figure 5.2 Routes of trace metals in an aquatic ecosystem.

Source: S.M. Jinks and M. Eisenbud, 1972, "Concentration factors in Aquatic Environment" Radia. Data Rep. 13, 243.

Table 5.3 Sampling parameters and collection and analysis frequencies of sediment at the Paducah Site for 1997

Station ^a	Parameter	Collection Frequency	Sample Type	Analysis Frequency
SS1, SS2, SS20, SS21, SS27, SS28,	^{137}Cs , ^{40}K , ^{237}Np , ^{239}Pu , ^{99}Tc , ^{230}Th , U, ^{235}U	Annually	Grab	Annually

^a See Figure 5.3

reference, or background sites, and can be used to compare with downstream data. SS20 and SS21 are on different creeks upstream of the plant discharges, whereas SS28 is located in a similar type stream providing a regional reference site. The downstream radionuclide concentrations are significantly higher than upstream concentrations for uranium and ^{99}Tc , the predominant radionuclides found at the plant. Uranium, the most prevalent radionuclide increase, is attributed to plant operations. This is verified by the assay values that are lower than natural occurring uranium. These results concur with past studies in which uranium was detected, resulting in fencing and posting Little Bayou Creek to make the public aware that prolonged exposure could result in an increase in a potential dose. Table 5.5 shows that uranium concentration in sediment has an overall downward trend. Other radionuclides, although present, are not significantly above background values.

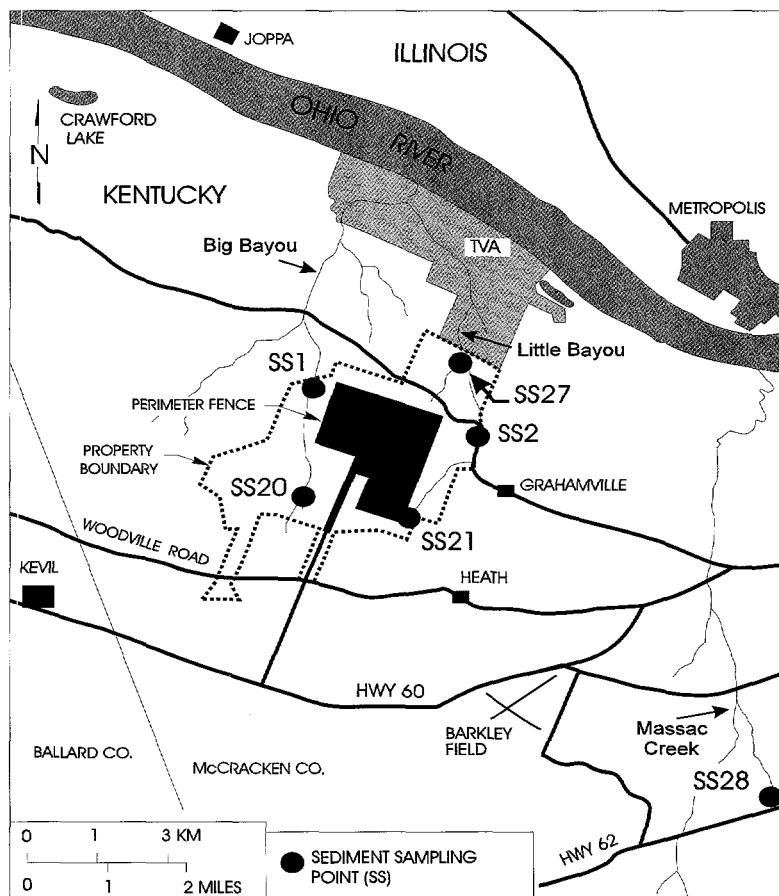


Figure 5.3 Sediment sampling locations at the Paducah Site.

Paducah Site

Table 5.4 Radionuclide sediment sampling results at the Paducah Site for 1997

Location	Parameter							
	⁹⁹ Tc (pCi/g) ^b	²³⁷ Np (pCi/g)	²³⁹ Pu (pCi/g)	²³⁰ Th (pCi/g)	¹³⁷ Cs (pCi/g)	⁴⁰ K (pCi/g)	²³⁵ U %	Uranium (g/g)
<i>Reference</i>								
<i>Big Bayou</i>								
SS20	0.186	NA	ND	0.056	NA	0.308	0.698	0.830
<i>Little Bayou</i>								
SS21	0.073	NA	ND	0.334	0.025	5.477	0.611	2.240
<i>Massac Creek</i>								
SS28	0.191	NA	ND	ND	NA	0.197	0.750	0.310
<i>Downstream Locations</i>								
<i>Big Bayou</i>								
SS1	0.590	ND	0.007	0.115	0.028	0.864	0.560	2.590
<i>Little Bayou</i>								
SS2	0.470	NA	ND	0.270	0.024	2.570	0.210	21.30

Table 5.5 Five year Uranium concentrations in sediment

Location ^a	Uranium (g/g)				
	1993	1994	1995	1996	1997
<i>Reference</i>					
SS20	1.8	1.42	0.9	5.1	0.83
SS21	2.9	2.93	2.2	2.6	2.24
SS28	0.65	1.4	0.51	1.8	0.31
<i>Downstream Locations</i>					
<i>Big Bayou</i>					
SS1	10.5	14.62	2.97	3.5	2.59
<i>Little Bayou</i>					
SS2	200	22.45	12.5	43.5	21.3
SS27	9.4	10.8	8.6	10.0	10.8

^a See Figure 5.3

Terrestrial Wildlife

In 1997, a total of eight deer were harvested in the West Kentucky Wildlife Management Area to monitor the effects of the Paducah Site on the ecology of the surrounding area. Two deer obtained as background samples from the Pennyrike State Forest were used for reference. Liver and muscle samples were analyzed for radionuclides. In addition, bone and thyroid samples were analyzed for the radionuclides strontium-90 (^{90}Sr) and technetium-99 (^{99}Tc), respectively. Because the liver and muscle tissue are considered consumable by hunters, these tissues are evaluated for radiological risks if analyses reveal detectable levels above background, or reference, deer. Bone and thyroid samples are used only as indicators of contamination. All tissue samples for 1997 had less than detectable quantities of radionuclides in reservation and background deer as summarized in Tables 5.6 and 5.7, respectively.

Because all samples showed less than detectable quantities of all radionuclides, no dose is assumed from eating reservation deer. Doses associated with DOE activities are presented in Section 6, "Dose."

Table 5.6 Paducah Site annual deer harvest for 1997, analysis of liver tissue for radionuclides

Deer	Radionuclide (pCi/g) ^a					
	^{234}U	^{235}U	^{238}U	^{239}Pu	^{237}Np	^{99}Tc
1	ND	ND	ND	ND	ND	ND
2	ND	ND	ND	ND	ND	ND
3	ND	ND	ND	ND	ND	ND
4	ND	ND	ND	ND	ND	ND
5	ND	ND	ND	ND	ND	ND
6	ND	ND	ND	ND	ND	ND
7	ND	ND	ND	ND	ND	ND
8	ND	ND	ND	ND	ND	ND
9 ^b	ND	ND	ND	ND	ND	ND
Background Deer						
10	ND	ND	ND	ND	ND	ND
11	ND	ND	ND	ND	ND	ND

^a 1pCi/g = 0.037 Bq/g

^b Duplicate

ND = Not Detected

Table 5.7 Paducah Site annual deer harvest for 1997 - analysis of muscle tissue for radionuclides

Deer	Radionuclide (pCi/g) ^a								Dose mrem
	²³⁰ Th	²³⁴ U	²³⁵ U	²³⁸ U	²³⁹ Pu	²³⁷ Np	⁹⁹ Tc		
1	ND	ND	ND	ND	ND	ND	ND	ND	0.00
2	ND	ND	ND	ND	ND	ND	ND	ND	0.00
3	ND	ND	ND	ND	ND	ND	ND	ND	0.00
4	ND	ND	ND	ND	ND	ND	ND	ND	0.00
5	ND	ND	ND	ND	ND	ND	ND	ND	0.00
6	ND	ND	ND	ND	ND	ND	ND	ND	0.00
7	ND	ND	ND	ND	ND	ND	ND	ND	0.00
8	ND	ND	ND	ND	ND	ND	ND	ND	0.00
9 ^b	ND	ND	ND	ND	ND	ND	ND	ND	0.00
Background Deer									
10	ND	ND	ND	ND	ND	ND	ND	ND	0.00
11	ND	ND	ND	ND	ND	ND	ND	ND	0.00

^a 1pCi/g = 0.037 Bq/g^b Duplicate

ND = Not Detected

6. Dose

Abstract

Most of the radioactive materials released from Department of Energy (DOE) operations at the Paducah Site are released in such low concentrations in the environment that standard monitoring procedures cannot detect them. Therefore, radiation doses to off-site populations are calculated with mathematical models. For 1997, the highest estimated dose a maximally exposed individual could have received from all combined DOE exposure pathways was 1.14 millirem (mrem). This dose is a small fraction of the applicable federal dose standard of 100 mrem/year.

Introduction

This section presents the estimated doses to individuals and the surrounding population from atmospheric and liquid releases from the Paducah Site. In addition, potential doses from special case exposure scenarios, such as deer meat consumption, are estimated.

Department of Energy (DOE) Order 5400.5, *Radiation Protection of the Public and the Environment*, limits the dose to members of the public to less than 100 mrem/year total effective dose equivalent from all pathways resulting from operation of a DOE facility. Information on the demography and land use of the area surrounding the plant and identification of on-site sources have indicated certain radionuclides and exposure pathways by which people can be exposed to radiation. Figures 6.1 and 6.2 give a comprehensive view of the possible pathways between radioactive materials released to the environment and human beings. In practice, only a few pathways constitute the major sources of exposure in any given situation.

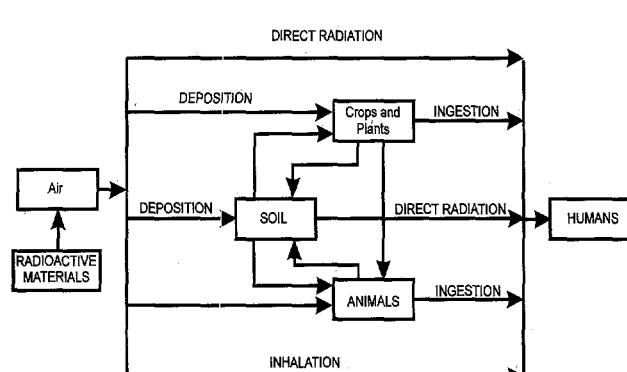


Figure 6.1 Possible pathways between radioactive material released to the atmosphere and individuals.

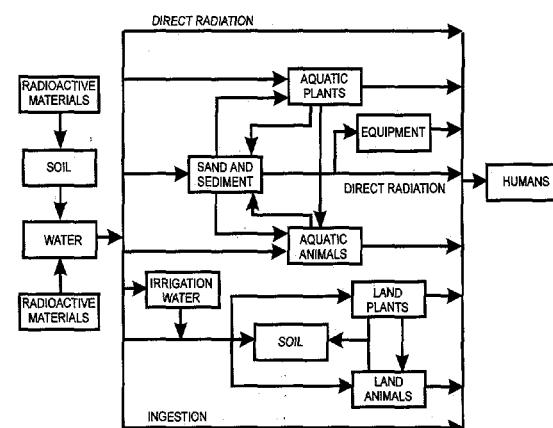


Figure 6.2 Possible pathways between radioactive materials released to surface water and individuals.

For the Phase I Remedial Action Site Investigation, CH2M Hill conducted a preliminary assessment of risk from contaminants from the Paducah Site to the health of the public (CH2M Hill 1990). This study identified four primary pathways that each could contribute greater than 1% to the total off-site dose: groundwater ingestion, sediment ingestion, wildlife ingestion, and exposure to direct radiation. To fully assess the potential dose to the public, a hypothetical group of extreme characteristics is used to postulate an upper limit to the dose of any real group. All dose estimates were rounded to approximate significant figures. Groundwater wells that supplied drinking water in the downgradient direction from the PGDP have been sealed to prevent use, resulting in a loss of that pathway. In 1995, the Northwest Plume Groundwater System began operation. Although less than one percent of the total dose commitment, airborne pathways are now included in the dose calculations.

Terminology/Internal Dose Factors

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

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

- *Committed effective dose equivalent*—the total internal dose (measured in millirem) received over a 50-year period resulting from the intake of radionuclides in a 1-year period. The committed effective dose equivalent is the product of the annual intake (picocuries) and the dose conversion factor for each radionuclide (millirems per picocurie).
- *Effective dose equivalent*—includes the committed effective dose equivalent from internal deposition of radionuclides and the dose from penetrating radiation from sources external to the body. This is a risk-equivalent value and can be used to estimate the health-effects risk to the exposed individual.
- *Total effective dose equivalent*—the sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). For purposes of compliance, dose equivalent to the whole body may be used as the effective dose equivalent for external exposures.
- *Collective effective dose equivalent*—a measure in person-rems of long-term radiation effects over a wide area. This measure is calculated by multiplying the average dose within defined areas by the number of persons living in that area.

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

Table 6.1 Internal dose factors for an adult

Isotope	Half-life (years)	Intake ^a (mrem/ Ci)			
		Inhalation ^b (soluble)	Inhalation ^b (slightly soluble)	Inhalation ^b (insoluble)	Ingestion
²³⁴ U	240,000	0.0027	0.0071	0.13	0.00026
²³⁵ U	710,000,000	0.0025	0.0067	0.12	0.00025
²³⁸ U	4,500,000,000	0.0024	0.0062	0.12	0.00023
⁹⁹ Tc	210,000	0.00000084	0.00000075		0.0000013
²³⁷ Np	2,100,000		0.49		0.0039
²³⁹ Pu	24,000		0.51	0.33	0.0043
²³⁰ Th	75,000		0.32	0.26	0.00053

^aSource: U.S. DOE. July 1988. *Internal Dose Conversion Factors for Calculations of Dose to the Public*, DOE/EH-00071.

^bIncludes allowances for skin adsorption.

Direct Radiation

The exposure pathway for direct radiation, external gamma radiation, was evaluated using the results of a 1991 thermoluminescent dosimeter survey covering the banks of Little Bayou Creek. The banks were determined to have radioactive contamination above natural background levels. The calculated dose values are the product of the exposure rate (milliroentgen per hour) from the radiological survey and the exposure time at a particular location.

To determine a very conservative exposure time for the Little Bayou Creek area, several assumptions were used. During 1997, the West Kentucky Wildlife Management Area allowed hunting and dog trials in this area from January 1 to March 31 and from September 1 to December 31 (213 days). For exposure in the creeks, an individual was assumed to hunt every other day during this period and spend 30 minutes in the area ditches and Little Bayou Creek bed. This exposure time is probably exaggerated because potential dose areas are fenced and signs are posted in this area stating that prolonged exposure could result in a dose above background. Also, observations by Kentucky Department of Fish and Wildlife personnel indicate that hunters spend very little time in creeks near the Paducah Site. The highest exposure rate occurs in Kentucky Pollutant Discharge Elimination System (KPDES) outfall 011 (which is fenced and posted before discharging into Little Bayou Creek). If this highest exposure rate is assumed for the above exposure times, then a dose can be calculated. Even using these extreme assumptions, the dose above background to this maximally exposed individual would be 1 millirem per year (mrem/year).

Contaminated Sediment in Little Bayou Creek

Exposure to contaminated sediment in Little Bayou Creek could occur during fishing, hunting, or other recreational activities. Contact and exposure could occur primarily through incidental ingestion of contaminated sediment or inhalation of contaminated particles. The estimated worst-case dose above background that would be received by an individual who was assumed to spend time in the West Kentucky Wildlife Management Area every other day during the hunting season would be 0.14 mrem/year.

Table 6.2 shows the dose calculation for ingestion of sediments in Little Bayou Creek. Upstream samples are assumed to be background and are subtracted from downstream sample results to arrive at a dose associated with site releases.

**Table 6.2 Annual dose estimate for 1997
Worst-case incidental ingestion of sediment from Little Bayou Creek**

Radionuclide	Intake (exposure) values ^a				Dose values ^b	
	Concentration (pCi/g)	Ingestion Rate (g/day)	Exposure Frequency (days/year)	Total Intake (pCi/year)	Ingestion Dose Conversion Factor (mrem/pCi)	Annual CEDE ^c (mrem/year)
<i>Downstream (SS 27)</i>						
²³⁴ U	1.176	0.80	106	99.72	0.00026	0.030
²³⁵ U	0.079	0.80	106	6.70	0.00025	0.003
²³⁸ U	3.580	0.80	106	303.58	0.00023	0.070
⁹⁹ Tc	5.772	0.80	106	489.47	0.00013	0.060
				Total		0.16
<i>Upstream (SS 21)</i>						
²³⁴ U	0.594	0.80	106	50.37	0.00026	0.01
²³⁵ U	0.001	0.80	106	0.08	0.00025	0.00002
²³⁸ U	0.741	0.80	106	62.84	0.00023	0.01
⁹⁹ Tc	0.073	0.80	106	6.19	0.00013	0.001
				Total		0.02
Total dose above background ^d						
						0.14

^a Exposure values from U.S. EPA 600/8-89-043, Exposure Factors Handbook, July 1989.

^b Dose factors from U.S. Department of Energy/EH0071, Internal Dose Conversion Factors for Calculation of Dose to the Public, July 1988

^c Committed effective dose equivalent as committed (50-year) dose from 1 year exposure (mrem/year).

^d Dose rounded to one significant figure based on ingestion rate estimate.

Ingestion of Deer

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

Terrestrial wildlife, such as deer, can come into contact with contaminated soil, ingest plants that have taken up contaminants or become coated with contaminated dust, or ingest contaminated water. Hunting is permitted in the West Kentucky Wildlife Management Area surrounding the Paducah Site, and the limit for deer harvest is two deer per person per season. The Paducah Site dose calculations normally assume that an individual kills two average-weight deer and consumes the edible portions of those deer during the year. The dose is calculated for each deer. In 1997, eight deer from the area near the Paducah Site were sampled along with two background deer. Neither DOE reservation deer nor reference deer from the Pennyroyal State Forest had measurable levels of radionuclides present. Therefore, no dose from consuming deer is assumed for 1997.

Airborne Radionuclides

At the Paducah Site, radioactive emissions to air are monitored to determine the extent to which the general public could be exposed and to demonstrate compliance with Environmental Protection Agency (EPA) regulations and DOE directives on radiation exposure to the public. Airborne radioactivity from DOE operations at the Paducah Site is normally too low to be detected in the presence of natural background radiation in the environment. Therefore, potential doses to the public are calculated with a dispersion model. This model calculates how measured quantities of released radionuclides mix with the atmosphere, where they travel, how they are mixed in the atmosphere, and where they could deposit. Once the dispersion is calculated, population data and concentration/dose conversion factors are used to calculate individual and population doses. These doses include exposure from all the pathways represented in Figure 6.1, although the primary pathway of exposure is inhalation. The primary contributor to the inhalation dose are ^{99}Tc .

The radiation dose calculations were performed using the Clean Air Act Assessment Package-88 (CAP-88) of computer codes. This package contains the EPA's most recent version of the AIRDOS-EPA computer code. The code uses a steady-state, Gaussian plume, atmospheric dispersion model to calculate environmental concentrations of released radionuclides. The code also uses Regulatory Guide 1.109 for food-chain models to calculate human exposures, both internal and external, to radionuclides deposited in the environment. The EPA's latest version of the DARTAB computer code then uses the human exposure values to calculate radiation doses to the public from radionuclides released during the year. The dose calculations use dose conversion factors from the latest version of the RADRISK data file, which the EPA provides with CAP-88.

On August 28, 1995, DOE began operation of its only radionuclide point source at Paducah, the Northwest Plume Groundwater System designed to remove trichloroethylene (TCE) and technetium (^{99}Tc) from groundwater. The Northwest Plume Groundwater System is the only DOE air source with sufficient releases to be used in calculating a dose. The facility is located at the northwest corner of the Paducah

Paducah Site

Site security area. The facility includes an air stripper to remove volatile organics from water and an ion exchange unit for the removal of ^{99}Tc . The air stripper is located upstream of the ion exchange unit. Emissions of ^{99}Tc were estimated using the mass differential between the analysis of the influent groundwater and the water leaving the air stripper. The ^{99}Tc concentration in the influent and effluent of the air stripper and the quantity of the water passing through the stripper were used to estimate the total quantity of ^{99}Tc emitted from the facility.

Nonpoint source emissions from DOE sources are minimal. Guidance from the EPA which stated that provisions of *Title 40, Code of Federal Regulations, Part 61, Subpart H*, applied to fugitive and diffuse emissions, was contained in correspondence dated March 24, 1992. The EPA also forwarded to the Paducah Site on September 21, 1992, questions pertaining to 1992 ambient air sampling results and their use as indications that fugitive and diffuse emissions from the Paducah Site operations were insignificant. The DOE reply satisfied all of the EPA's questions except the one pertaining to resuspension of contaminated soil, which could result from such activities as well drilling activities or vehicular traffic upon contaminated earth. The question as to whether such activities actually constitute fugitive or diffuse sources was forwarded to EPA headquarters for resolution. DOE has not yet received a response to this question. It is not expected that any activity that would result in fugitive or diffuse emissions would result in emissions that would be distinguishable from background at off-site locations.

During 1997, a drum of ^{99}Tc contaminated waste ruptured inside the C-746-Q waste storage building. The building is dyked and maintains controlled access. As a result of the rupture the waste was collected and fixed to prevent the spread of contaminants and to allow safe disposal. Temporary control structures were erected inside the building to prevent any movement of the spilled waste during the fixing process. A conservative estimate of the quantity of ^{99}Tc leaving the building via the ventilation system during the rupture and cleanup operation was 4.45×10^{-4} curies of ^{99}Tc .

Another potential fugitive or diffuse source of radionuclides, albeit a minor one, results from the decontamination of machinery and equipment used in remediation activities such as well drilling. The equipment is washed with high-powered sprayers to remove any contaminants (radiological or nonradiological). The contaminants originate from the soil and groundwater. The concentrations of contaminants on the equipment are so small that under most circumstances contamination cannot be distinguished from background.

For calculating dose from the Northwest Plume Groundwater System, computer codes used facility specific radionuclide emission data for 1997, meteorological data collected from 1989 through 1993 at the 60-meter station at the Paducah Site, and dose conversion factors specified in the CAP-88 codes. Organ weighing factors used in estimating effective dose equivalents are also based on International Commission on Radiological Protection recommendations (ICRP 1979).

The calculated 50-year committed effective dose equivalent (internal) from DOE air sources to the maximally exposed individual was estimated to be 6.2×10^{-4} (0.00062) mrem (6.2×10^{-6} mSv), which is well below the 10-mrem limit. The dose to the maximally exposed individual, who under most circumstances is the person living closest to the plant in the predominant wind direction, is calculated each year. The maximally exposed individual for 1997 is located approximately 1170 meters (3836 feet) north northeast of the plant site.

The collective effective dose equivalent is a good measure of long-term radiation effects over a wide area. The 1997 collective effective dose equivalent for the 500,500 residents within 80 kilometers (50 miles) from DOE emissions was estimated to be 2.6×10^{-3} (0.0026) person-rem (2.6×10^{-5} person SV). This dose can be compared with a collective dose for the same population of 200,000 person-rem/year from natural background radiation.

Conclusions

Table 6.3 contains a summary of the dose for 1997 from radiological contaminants that could be received by a member of the public living near the plant assuming worst-case exposure from all major pathways. The groundwater pathway from DOE sources is assumed to contribute nothing to the population or maximally exposed individuals dose because all residents have been supplied with public water by DOE. Figure 6.3 shows the potential annual dose for the past five years. The calculated maximum combined (internal and external) dose to an individual would be 1.14 mrem/year for current and historical DOE activities. This level is well below the DOE annual dose limit of 100 mrem/year to members of the public. The major contributors to the dose are direct radiation from the banks of Little Bayou Creek and ingestion of sediment in or near the Little Bayou Creek bed.

The potential exposure areas of the creek have been fenced, and signs have been posted to notify the public of the elevated radiation levels.

Estimates of radiation doses presented in this report were calculated using the dose factors provided by DOE (DOE 1988). These dose factors are based on International Commission on Radiological Protection Publication 30, *Limits of Intakes of Radionuclides by Workers* (ICRP 1979).

Table 6.3 Summary of potential radiological dose from the Paducah Site for 1997 - Worst-case combined exposure pathways

Pathway	Dose ^{a,b} (Mrem/year)	Percent of total	Maximum allowable exposure, DOE Order 5400.5 (mrem/year)
Ingestion of sediments	0.14	12	
Ingestion of deer meat	0	0	
Direct radiation (Little Bayou Creek)	1	88	
Atmospheric releases	0.00062	<1	
Total annual dose above background (all pathways)	1.14		100

^a Dose values were rounded to yield the correct number of significant digits based on all the 1996 data used to estimate the worst-case dose from all exposure pathways and from estimated significant figures in atmospheric releases per DOE/EH-0173T, Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance.

^b 100 mrem = 1 mSv

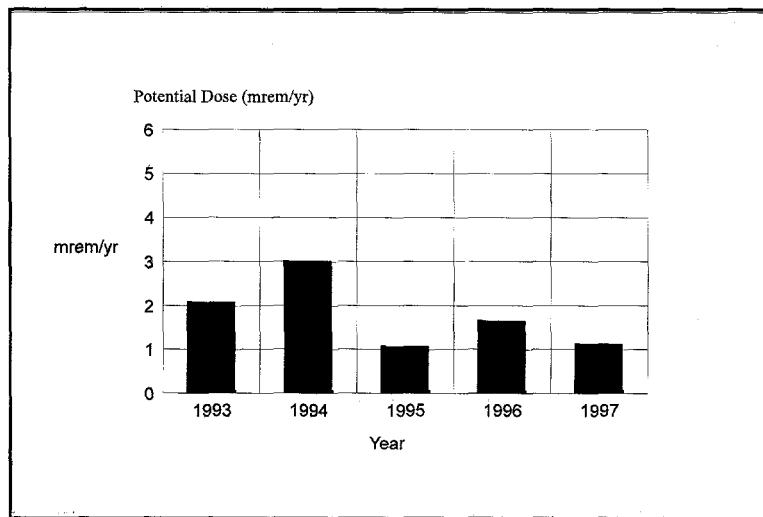


Figure 6.3 Potential radiological dose from the Paducah Site, 1993 thru 1997.

The DOE maximum allowable dose from all pathways is 100 mrem.

7. Nonradiological Effluent Monitoring

Abstract

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

In 1997, there were five Kentucky Pollutant Discharge Elimination System (KPDES) exceedences at the Department of Energy (DOE) outfalls. The exceedences were for reportable KPDES effluent exceedences (discharges exceeding the permit limits) that occurred for pH, TCE, oil and grease, and chronic toxicity. No Notices of Violations were issued due to these permit exceedences.

In 1997, DOE had three point sources for air emissions. The combined emissions from these sources are small; therefore, the Paducah Site is considered a minor source in accordance with Clean Air Act.

Introduction

Responsibility for nonradioactive airborne emission sources at the Paducah Gaseous Diffusion Plant (PGDP) was turned over to United States Enrichment Corporation (USEC) as a result of the lease agreement between USEC and Department of Energy (DOE). Only a few fugitive sources, such as gravel roads, dirt piles (resulting from construction excavation), and metal scrap pile windage, remains the responsibility of DOE. These sources are not considered to be major.

Monitoring of nonradiological parameters in liquid effluents is documented in the Paducah Site *Environmental Monitoring Plan* (LMES 1995) and is further defined in the Kentucky Pollutant Discharge Elimination System (KPDES) permit, KY0004049, and in Kentucky Division of Waste Management (KDWM) landfill permit 073.14 as well as the DOE landfill KPDES permit, KY0100072. Sampling and analytical activities are the responsibility of Energy Systems, but those services are procured from Utility Services. The Environmental Monitoring Section, part of the Utility Services Environmental, Safety, and Health Division, provides sampling support. The analytical laboratory, part of the Utility Services Production Support Division, provides analytical measurements. Effluents are monitored for nonradiological parameters as listed on the permit governing the discharge.

Airborne Effluents

Airborne Effluent Applicable Regulations

The Clean Air Act at the Paducah Site is administered by the Kentucky Division for Air Quality (KDAQ). DOE has responsibility for four air emission sources as a result of the lease agreement with USEC. These four sources are two separate fluorescent lamp crushers, four trichloroethylene (TCE) tanks, and the Northwest Plume Groundwater System. 20,853 pounds of fluorescent lamps were crushed in 1997 by one

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Northwest Plume Groundwater System. 20,853 pounds of fluorescent lamps were crushed in 1997 by one crusher. The four TCE tanks located at C-733 were empty throughout 1997, and no plans exist to use the tanks.

Airborne Effluent Monitoring Program

The largest sources of air emissions for the Paducah Site in 1997 were UF₆ cylinder refurbishment activities, the Northwest Plume Groundwater System, and Northeast Plume Containment System. The UF₆ cylinder refurbishment activities generated an estimated 5 tons of particulate emissions or dust. Most of the dust was generated by grit blasting the rusty UF₆ cylinders before painting. Approximately 1.5 tons of Volatile Organic Compounds (VOCs) were released during cylinder painting. The Clean Air Act defines particulate and VOC emissions as criteria pollutants. A minor source is limited to 100 tons (or less) per year of each of these criteria pollutants. If greater quantities of pollutants are emitted, then the source is classified as a major source. Table 7.1 summarizes 1997 emissions and compares these emissions to the threshold limit amount for a major source. A minor source has less stringent permit requirements because of the reduced potential for health effects from the smaller amount of emissions.

The Clean Air Act also limits the emissions from a minor source of Hazardous Air Pollutants (HAPs) to 10 tons per year for each individual pollutant and 25 tons per year for all HAPs combined. The greatest amount of HAP emitted in 1997 was approximately 2 tons of TCE from the Northwest Plume Groundwater System and the Northeast Plume Containment System. Smaller amounts of HAPs were released from the paint used for UF₆ cylinder refurbishment. These also are summarized in Table 7.1.

Table 7.1 Comparison of 1997 air emissions to Clean Air Act major source threshold amounts

Pollutant	Calculated Emission	Major Source Threshold
Criteria Pollutants		
Particulate	5 tons	100 tons
Volatile Organic Compounds	3.52 tons	100 tons
Hazardous Air Pollutants (HAPs)		
TCE	2.03 tons	10 tons
MEK	0.01 tons	10 tons
Toluene	0.01 tons	10 tons
Total HAPs	2.05 tons	25 tons

Liquid Effluents

Liquid Effluent Applicable Regulations

The Clean Water Act is administered for the Paducah Site by the Kentucky Division of Water (KDOW) through the KPDES Wastewater Discharge Permitting Program. The current sitewide KPDES permit became effective on November 1, 1992. This permit contains limits based on water quality criteria with a zero flow receiving stream. The Paducah Site adjudicated portions of the permit that contained unattainable effluent limits and implemented the portions of the permit not under adjudication. An agreed order was signed in April 1996, which stays the limits for temperature, phosphorus, pH, cadmium, chromium, copper, lead, nickel, and zinc while studies could be conducted. As a part of the Agreed Order pH, temperature and metals studies were carried on during 1996 and 1997. The pH and temperature studies were completed in 1997. The studies indicated USEC discharges were effecting the pH and temperature in receiving streams. USEC is implementing temperature and pH controls for effluent discharges. DOE outfalls were not effecting receiving streams. The metals study is ongoing with inconclusive results during 1997.

In addition to the two outfalls listed on the site wide KPDES permit, DOE also has a KPDES permit for the landfill. This permit was issued by the KDOW and became effective on September 1, 1995.

Liquid Effluent Monitoring Program

Nonradiological effluent monitoring for four outfalls at PGDP is under the jurisdiction of DOE, see Figure 4.1. These DOE outfalls (001, 015, 017 and 018) plus the landfill outfall (K001) are monitored for KPDES parameters. During 1997, DOE accepted responsibility for outfalls, 015 and 001. DOE retained no point sources for liquid effluents as a result of the lease agreement but did retain responsibility for any historic pollutants that could result from past operations at the plant.

Monitoring of the DOE outfalls was conducted in accordance with the KPDES permit. *Title 40, Code of Federal Regulations, Part 136* (40 CFR 136), lists the specific sample collection, preservation, and analytical methods acceptable for the types of pollutants to be analyzed. Preservation in the field is conducted per 40 CFR 136, and chain-of-custody procedures are followed after collection and during transport to the analytical laboratory. The samples are then accepted by the laboratory and analyzed per 40 CFR 136 procedures for the parameters required by the KPDES permit.

Surface runoff from the closed C-746-S residential landfill and the C-746-T inert landfill was monitored quarterly. A grab sample of the landfill runoff was monitored for chloride, sulfate, pH, sodium, uranium, iron, total organic carbon, total suspended solids, total dissolved solids, and specific conductivity. The samples taken include landfill runoff, upstream of the runoff discharge, and downstream of the discharge at KPDES Outfall 018. Sampling is performed to comply with KDWM requirement for operation of the contained landfill.

Liquid Effluent Monitoring Results

Analytical results are reported to the KDOW each month in two discharge monitoring reports. The four DOE site outfalls (001, 015, 017 and 018) are included in the plant discharge monitoring report while the DOE landfill has its own separate discharge monitoring report. The discharge monitoring report included the status of DOE outfalls, a detection limit discussion, and toxicity data collected during the month (if applicable).

Three exceedences of permit limits occurred in 1997 at the DOE retained outfalls and one exceedence at a USEC outfall for a legacy problem, see Table 7.2. The DOE landfill outfall experienced one KPDES permit exceedence.

Table 7.2 KPDES Exceedence Summary for 1997

Month	Outfall	Exceedence
February	011	TCE
March	017	Oil & Grease
July	UL001	pH
August	001	Chronic Toxicity
October	017	pH

8. Nonradiological Environmental Surveillance

Abstract

The purpose of the nonradiological environmental surveillance program at the Paducah Site is to assess the effects of the Department of Energy operations on the site and the local environment and population. Surveillance includes analysis of air, surface water, groundwater (see Section 9), sediment, soil, vegetation, and fish and other aquatic life. Surveillance results indicated that nonradionuclide concentrations in most sampled media were within applicable standards.

Introduction

Nonradiological environmental surveillance at the Paducah Site involves sampling and analysis of air, surface water, groundwater (see Section 9 for groundwater surveillance results), sediment, soil, vegetation, and fish and other aquatic life.

As a result of the transfer of the production part of the plant to the United States Enrichment Corporation (USEC), major air emission sources and 14 of the 16 active Kentucky Pollutant Discharge Elimination System (KPDES) liquid effluent discharges were transferred to USEC.

Ambient Air

The Paducah Site is not required to conduct ambient air monitoring.

Surface Water

Routine surface water monitoring that is not required by the KPDES permit is performed at the Paducah Site as part of the environmental surveillance program. The net impact of the Paducah Site's activities on surface waters is evaluated by comparing data from samples collected at a reference location at Massac Creek with information from samples collected upstream and downstream of the facility from Little Bayou and Big Bayou Creeks. Bimonthly surface water samples are collected at six locations with another location being selected for biannual sampling, see Figure 8.1. The samples are analyzed for general water quality parameters, volatile organic compounds, and selected radionuclides and dissolved metals, see Table 8.1.

Surveillance Results

These locations are monitored to maintain data that could possibly be used to explain or trace unusual results at other locations. These data can be compared from year to year to determine if significant changes have occurred. The data can also be compared using upstream and downstream locations around

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the Paducah Site, see Tables 8.2 and 8.3. Historical comparisons between 1996 and 1997 data did not identify any unusual trends. Comparison between upstream and downstream locations does not show any significant differences.

Location SW 1 and SW 5 are both located on Big Bayou Creek. Location SW 1, upstream Big Bayou Creek, is located above all DOE and USEC discharges, while SW 5 is located on Big Bayou Creek downstream of DOE and USEC liquid effluent discharges. Comparison of the data from these locations identified chloride at the downstream location being nearly four times higher than the upstream site. Iron data revealed that the downstream location was nearly half that of the upstream location. The 1997 chloride and iron data are similar to the 1996 data.

Locations SW 29 and SW 30, both involving the Ohio River water, are monitored to obtain information on

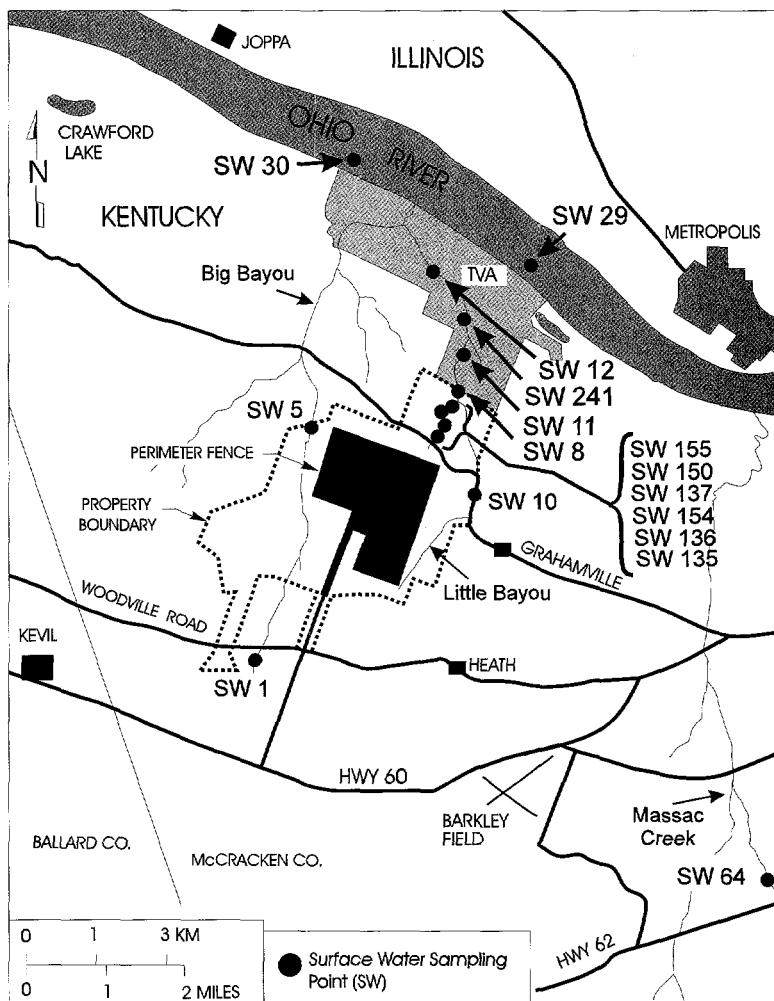


Figure 8.1 Surface water monitoring locations at the Paducah Site.

Table 8.1 Nonradiological sampling parameters and collection and analysis frequencies of surface water at the Paducah Site for 1997

Station ^a	Parameter	Collection Frequency	Sample Type	Analysis Frequency
SW1,SW5	Chloride, BOD, Temperature, Hardness, pH, P, TSS, Al, Cd, Cr, Cu, Fe, Pb, Ni, Zn, Acetone, Isopropanol, TCE, PCB	Bi-monthly	Grab	Bi-monthly
SW10, SW11				
SW29,SW64				
SW8	TCE, ⁹⁹ Tc	Semi-annual	Grab	Semi-annual

^a See Figure 8.1

Table 8.2 1997 Big Bayou Creek Surveillance

	SW 1 Upstream Big Bayou	SW 5 Downstream Big Bayou
Aluminum (mg/L)	0.54	ND
Cadmium (mg/L)	ND	ND
Chloride (mg/L)	13.87	50.76
Chromium (mg/L)	ND	ND
Copper (mg/L)	ND	ND
Iron (mg/L)	0.60	0.28
Lead (mg/L)	0.002	0.003
Nickel (mg/L)	ND	ND
Phosphorus (mg/L)	0.05	0.18
Zinc (mg/L)	ND	ND
pH (SU)	7.73	7.76
PCB (g/L)	ND	ND
TCE (g/L)	ND	ND

Table 8.3 1997 Ohio River Surveillance

	SW 29 Upstream Ohio River	SW 30 Downstream Ohio River
Chloride (mg/L)	10.36	13.03
Fluoride (mg/L)	0.11	0.12
Nitrate as Nitrogen (mg/L)	1.02	ND
Phosphate (mg/L)	ND	ND
Sulfate (mg/L)	21.44	32.55
Hexavalent Chromium (mg/L)	ND	ND

any unusual results that could show up in KPDES discharges. Ohio River water is used in USEC's water treatment plant to provide potable, fire, and cooling water for the PGDP. SW 29 is above where the DOE and USEC effluent discharges into the Ohio River through Big Bayou Creek. SW 30 is below the location where Big Bayou Creek discharges into the Ohio River. The 1997 data shows an elevation in chloride and sulfate at both upstream and downstream locations and reductions in phosphate and hexavalent chromium. More detailed data can be found in Appendix C.

Sediment

Stream sediments are 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 filtered by certain organisms, or become attached to plant surfaces. Pollutants in solution can adsorb on suspended organic and inorganic solids or be assimilated by plants and animals. The suspended solids, dead biota, or excreta settle to the bottom and become part of the organic substrata that support the bottom-dwelling community of organisms. Figure 5.2 shows possible exposure routes of trace metals in an aquatic ecosystem (Jinks and Eisenbud 1972).

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Sediments play a significant role in aquatic ecology by serving as a repository for chemical substances that pass via bottom-feeding biota to the higher trophic levels. Soluble pollutants introduced into a body of water reach the bottom sediment primarily by adsorption on suspended solids that later deposit on the bottom. The deposited remains of biota that have absorbed pollutants may also be an important source of chemical pollutants that enter the food chain.

Sediment Surveillance Program

Because DOE retained responsibility for historic environmental issues and problems, ditch sediments are tracked through a nonradiological environmental surveillance program, which focuses on monitoring for polychlorinated biphenyls (PCBs). Sediment samples were taken from six locations, see Figure 8.2.

Table 8.4 lists the monitoring parameters and the collection and analysis frequencies for sediment samples.

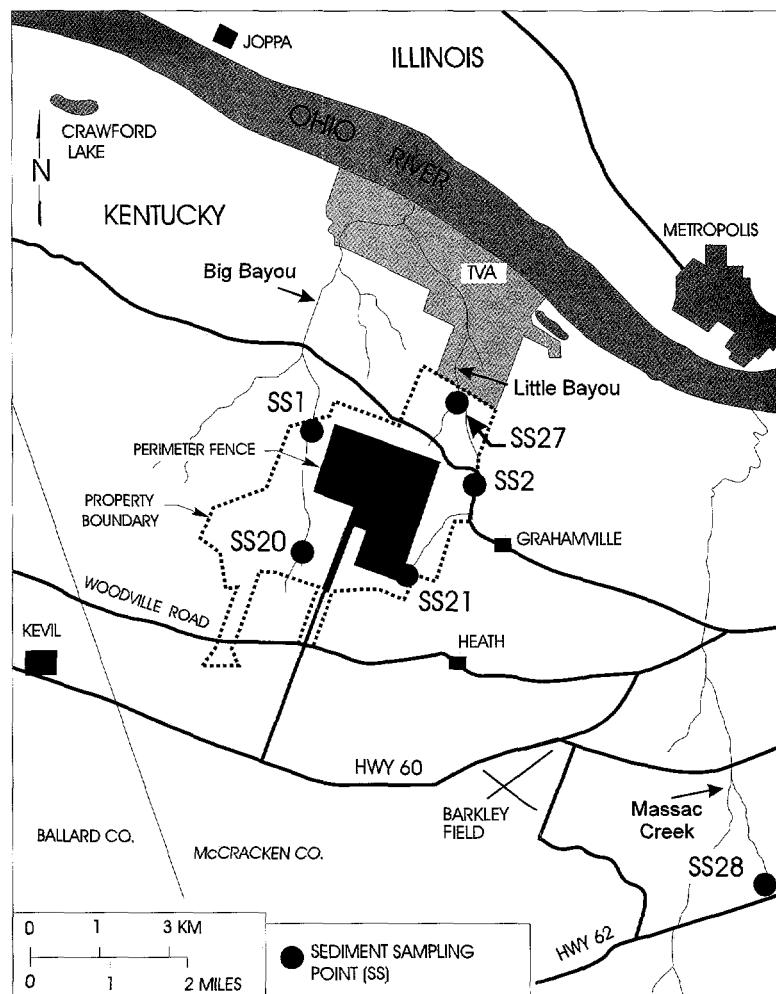


Figure 8.2 Sediment sampling locations at the Paducah Site.

Table 8.4 Nonradiological sampling parameters and collection and analysis frequencies of sediment at the Paducah Site for 1997

Station ^a	Parameter	Collection Frequency	Sample Type	Analysis Frequency
SS1, SS2, SS20, SS21, SS27, SS28,	PCBs, Ag, Al, As, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, Hg, Mg, Mn, Na, Ni, Pb, Sb, Ti, Tl, V, Zn	Annually	Grab	Annually

^a See Figure 8.2

Sediment Surveillance Results

PCB results at location SS 2 for 1993–1997 are shown in Table 8.5. Results for this location are shown because historically this location has had the highest PCB concentrations at the Paducah Site. Due to data from past studies in which PCBs were detected, signs were posted at Little Bayou Creek to make the public aware of the PCB contamination.

The sampling results for other nonradiological constituents are summarized in Table 8.6. Historically, nonradiological sediment sampling results have shown varying amounts of fluctuation. These fluctuations are monitored to assess any trending and potential impacts. These fluctuations will continue to be assessed. Big and Little Bayou creeks and KPDES-permitted discharge ditches were investigated during administrative consent order activities. Remedial alternatives were drafted (SAIC 1991a) and were reviewed by the Environmental Protection Agency (EPA) and the Kentucky Department for Environmental Protection (KDEP). The current plan is to address the sediments as part of the surface water integrator unit. According to the Draft Site Management Plan, the surface water unit is currently scheduled to be addressed after sources of offsite contamination are addressed, which will prevent recontamination of the sediments.

Soil

Because the major source of soil contamination is from air pathways and because DOE no longer controls any major air point sources, soil surveillance is not included in this report.

Vegetation

Because DOE no longer operates any major sources of air emissions, vegetation surveillance activities are not included in this report.

Fish and Other Aquatic Life

The Biological Monitoring Program (BMP) for the Paducah Gaseous Diffusion Plant (PGDP) was implemented in 1987 by the Environmental Sciences Division (ESD) at Oak Ridge National Laboratory, Oak Ridge, Tennessee. Initially, the monitoring was performed under a subcontract with the University of Kentucky, but after 1990, the monitoring was conducted by ESD staff. This study includes both DOE and USEC outfalls, but is being funded and managed by DOE. The objectives of BMP are to (1) demonstrate that the effluent limitations established for PGDP protect and maintain the use of Little Bayou and Big Bayou creeks for growth and propagation of fish and other aquatic life, (2) characterize potential

Table 8.5 PCB results (in g/g) for sediment samples from location SS2, 1993-1997

1993	2.0
1994	1.4
1995	<0.1
1996	1.33
1997	<0.1

Table 8.6 Nonradiological sediment sampling results for 1997

Location ^a	Arsenic mg/kg	Beryllium mg/kg	Chromium mg/kg	Cobalt mg/kg	Copper mg/kg	Lead mg/kg	Magnesium mg/kg	Mercury mg/kg	Potassium mg/kg	Titanium mg/kg	Vanadium mg/kg	Zinc mg/kg	Parameter
													Reference
SS20	ND	ND	8.3	ND	ND	ND	85.8	NA	ND	ND	ND	17.8	ND
SS21	ND	ND	22.4	6.7	7.1	ND	474	ND	315	66.9	35.2	17.1	
SS28	ND	ND	6.1	ND	ND	ND	54.1	ND	ND	ND	ND	ND	ND
<i>Downstream Locations</i>													
<i>Big Bayou</i>													
SS1	ND	ND	19.4	ND	6.0	ND	156	ND	ND	ND	ND	17.7	ND
<i>Little Bayou</i>													
SS2	6.1	ND	65.9	16.2	8.7	26.2	390	ND	ND	ND	44.4	57.4	
SS27	ND	ND	79.7	ND	7.0	ND	63.8	ND	ND	ND	15.1	22.5	

^a See Figure 8.2

environmental impacts, and (3) document the effects of pollution abatement facilities on the animals that live in the stream. The BMP is not required in either the Agreed Order or the Kentucky Pollutant Discharge Elimination System (KPDES) permit; however, biological monitoring of the Department of Energy (DOE) facilities at PGDP are conducted to satisfy requirements of DOE Order 5400.1.

The BMP for PGDP consists of three major tasks: (1) effluent toxicity monitoring, (2) bioaccumulation studies, and (3) ecological surveys of fish communities. A summary of the BMP activities from January to December 1997 is provided, although activities conducted outside this time period are included as appropriate. A detailed report of the 1997 BMP was published in May 1998 (Kszos 1998) and is available from the National Technical Information Service, U.S. Department of Commerce.

Study Area

Three sites on Big Bayou Creek, Big Bayou Creek kilometer (BBK) 12.5, BBK 10.0, and BBK 9.1; one site on Little Bayou Creek, Little Bayou Creek kilometer (LUK) 7.2, see Figure 8.3; and one off-site reference station on Massac Creek, Massac Creek kilometer (MAK) 13.8, were routinely sampled to assess the ecological health of the stream. Two additional sites (LUK 9.0, and LUK 4.3) were sampled as part of the bioaccumulation monitoring task. Fish community sampling and bioaccumulation sampling were conducted twice annually in the spring and fall. KPDES outfalls evaluated for effluent toxicity in 1997 included Outfalls 001, 006, 008, 009, 010, 013, 015, 016, 017, and 018. In addition, the toxicity of effluent from K001 was evaluated by Central Virginia Laboratories and Consultants.

Toxicity Monitoring

The toxicity of effluents from the continuously flowing outfalls (001, 006, 008, 009, and 010) and the intermittently flowing outfalls (013, 015, 016, 017, and 018) were monitored for toxicity with fathead minnow larvae. In addition, the toxicity of effluent from Outfall 001 was monitored with a water flea (*Ceriodaphnia dubia*). Toxicity tests were conducted quarterly as required by the KPDES permit. The 25% inhibition concentrations (IC25: that concentration causing a 25% reduction in fathead minnow growth or *Ceriodaphnia* survival compared with the control) were determined for each test. The chronic toxicity unit rating ($TU_c=100/IC_{25}$) is required as a compliance endpoint in the KPDES permit. The higher the TU_c , the more toxic an effluent. Because Little Bayou and Big Bayou creeks have been determined to have a low flow of zero, a TU_c 1.0 would be considered a noncompliance (for the continuously flowing outfalls) and an indicator of potential instream toxicity.

The toxicity of effluent from K001 was evaluated with fathead minnow larvae and *Ceriodaphnia*. This discharge is rainfall dependant. If there is sufficient rainfall, two samples are collected within 4 hours of each other once per quarter. The 50% lethal concentration (LC50; that concentration causing 50% mortality in 48 h) was determined for each test. The acute toxicity unit rating ($TU_a=100/LC_{50}$) is required as a compliance endpoint in the KPDES permit.

Toxicity tests of the continuously flowing outfall were conducted in March, May, August, and December 1997. Effluent from Outfall 001 exceeded the permit limit (TU_c 1.0) in August with a $TU_c = 8.34$. This is the first occurrence of a fathead minnow test with a TU_c 1.0 for Outfall 001 since testing began

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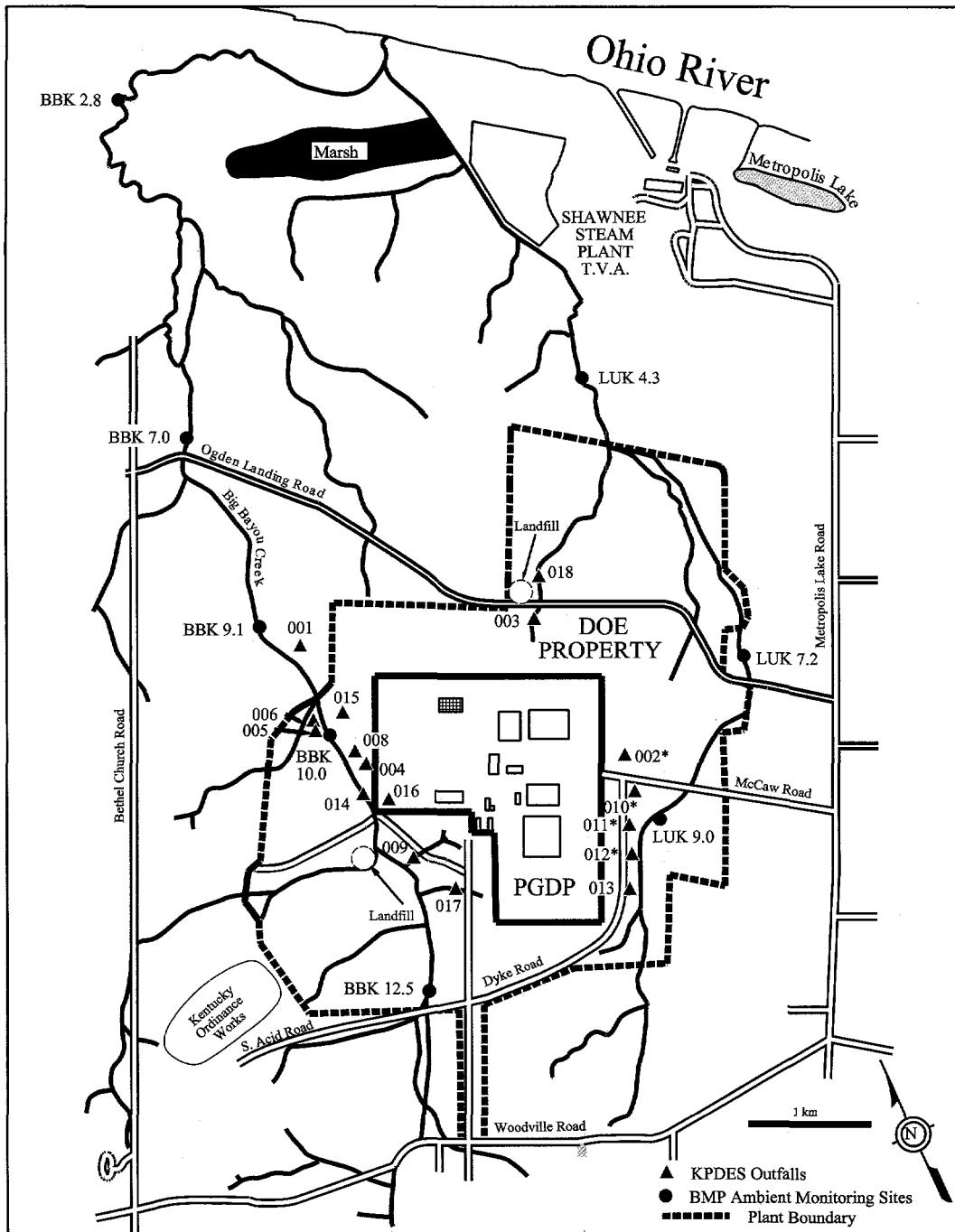


Figure 8.3 Biological Monitoring Sampling locations.

in October 1991. The confirmatory test conducted in September resulted in a TUc < 1.0, demonstrating that the effluent was no longer toxic. The TUcs for the Outfalls 006, 008, 009, and 010 were less than 1.0 for all tests conducted in 1997.

Toxicity tests of the intermittent outfalls were conducted in January, April, July, and December. The only cases of TUc 1.0 were for the fathead minnow tests of Outfall 015 in July and Outfall 016 in April. The TUc for Outfall 015 in July was 2.74. This is the first case of a TUc 1.0 for Outfall 15 since November 1994. The subsequent test of Outfall 015 in December resulted in TUc < 1.0. The TUc for Outfall 016 in April was 19.61. Similar to Outfall 015, this is the first case of a TUc 1.0 for Outfall 15 since November 1994. The subsequent tests of Outfall 016 in July and December resulted in TUcs < 1.0, demonstrating that the effluent was no longer toxic.

Toxicity tests of K001 were conducted in April, July, and November 1997. The TUa for all tests was less than 1.0. Thus, there was no evidence of acute toxicity in any of the samples.

Bioavailability Study

In December 1996, a bioavailability study was initiated to develop alternative metal limits for cadmium, chromium, copper, lead, nickel, and zinc. As stipulated in the Agreed Order, DOE/USEC must demonstrate to the satisfaction of the Cabinet that a more appropriate analytical technique or criteria is available that provides a better measurement of levels of metals present that would be toxic to aquatic life. Phase I of the study developed alternative metal limits for continuously discharging outfalls and was completed in 1997. A report detailing the results of Phase I, *Bioavailability Study for the Paducah Gaseous Diffusion Plant* (Phipps 1997), was submitted to the Kentucky Division of Water for comment on January 30, 1998.

Bioaccumulation Monitoring

The primary objective of the 1996-97 bioaccumulation monitoring was to evaluate changes in PCB contamination in fish from Little Bayou Creek that may be a result of DOE and USEC plant practices designed to decrease PCB inputs. Longear sunfish (*Lepomis megalotis*) were collected for PCB and mercury analysis from Little Bayou Creek in fall 1996, and spring and fall 1997. To evaluate the maximum concentrations likely in fish near the PGDP, larger fish (spotted bass; *Micropterus punctulatus*) were analyzed for mercury and PCBs.

Average PCB concentrations in sunfish from Little Bayou Creek were higher than in fish from reference sites on all sampling dates, see Table 8.7. On two of three dates, highest mean PCB concentrations were found in fish from the middle site (LUK 7.2) on Little Bayou Creek, with an abrupt decrease in average concentration at the downstream site. Previously, mean PCB concentrations in sunfish from Little Bayou

Creek had always been highest at the uppermost site nearest PGDP discharges (LUK 9.0), with a progressive decrease at the two downstream sites. The change in the downstream pattern of PCB accumulation in sunfish may indicate that chronic PCB discharges from the PGDP facility are becoming less predominant relative to in-stream sources in determining levels of contamination in fish. PCB

Paducah Site

Table 8.7 PCB concentrations in fish ($\mu\text{g/g}$)

Site ^a	Species	Mean ^b	SE	Range	n
<i>October 1996</i>					
BBK 9.1	Spotted Bass	0.45	0.07	0.30 - 0.58	4
LUK 9.0	Longear Sunfish	0.64	0.13	0.35 - 1.19	6
LUK 7.2	Longear Sunfish		0.07-	0.48 - 0.93	6
LUK 4.3	Longear Sunfish	0.13	0.06	<0.01 - 0.32	5
Reference (Hinds Cr, Tn)	Redbreast Sunfish	<0.01	-	-	4
<i>May 1997</i>					
LUK 9.0	Longear Sunfish	0.62	0.062	0.47 - 0.78	6
LUK 7.2	Longear Sunfish	0.48	0.12	0.22 - 0.85	6
LUK 4.3	Longear Sunfish	0.12	0.04	<0.01 - 0.27	5
Reference (Massac Cr, Ky)	Longear Sunfish	<0.01			4
<i>October 1997</i>					
LUK 9.0	Longear Sunfish	0.37	0.10	0.13 - 0.66	6
LUK 7.2	Longear Sunfish	0.48	0.15	0.12 - 1.11	6
LUK 4.3	Longear Sunfish	0.06	0.01	<0.01 - 0.12	6
Reference (Massac Cr, Ky)	Longear Sunfish	<0.01			4

^a BBK = Big Bayou Creek kilometer, LUK = Little Bayou Creek kilometer.

^b Value of $\frac{1}{2}$ the detection limit was used in calculating means for samples.

concentrations in sunfish in Little Bayou Creek remain low in comparison to concentrations observed in 1993, see Figure 8.4. Concentrations have not decreased appreciably since a precipitous drop in 1994. The continued low levels of PCB contamination in fish in Little Bayou Creek provides evidence of effective controls and remediation of sources within PGDP. Continued monitoring will help assess whether additional controls are needed.

Average mercury concentrations in spotted bass from Big Bayou Creek in 1996 were typical of previous years. Low mercury concentrations in 1997 were probably a consequence of our inability to obtain larger specimens, and most likely does not represent a temporal change. Mercury concentrations in larger bass

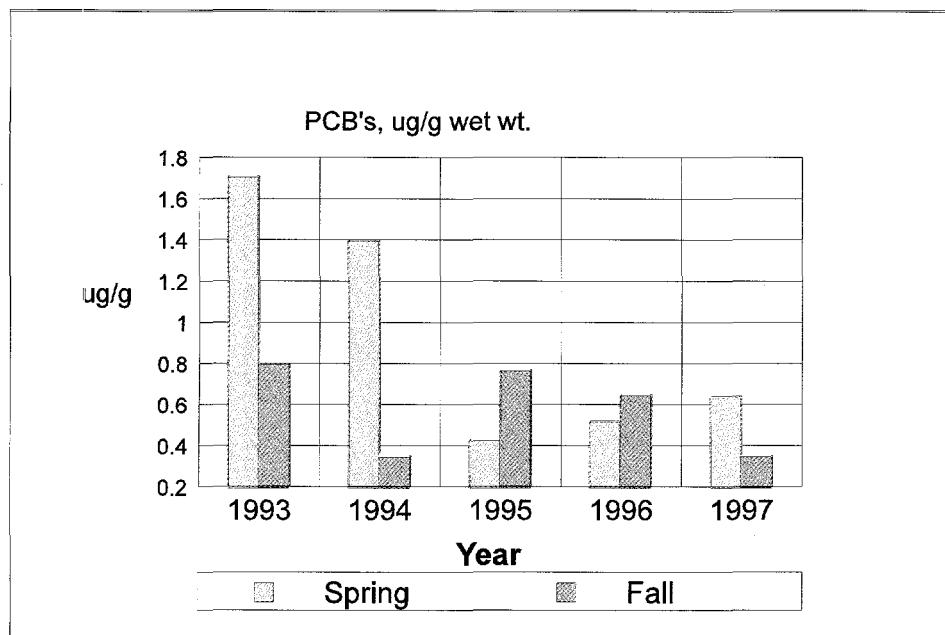


Figure 8.4 Average PCB concentrations in sunfish.

collected from Big Bayou Creek may approach or exceed common human health consumption limits. However, it appears that at least part of the mercury burden in Big Bayou Creek bass is attributable to natural factors and not to PGDP mercury inputs. Analysis of water samples from Big Bayou Creek above and below PGDP discharges found total mercury concentrations in the creek to be slightly higher downstream from PGDP, but well within the range of natural background concentrations for streams.

Forage Fish Study

Whole-body fish samples were also collected in 1997. The primary objective of this effort was to provide whole-body fish data that could be used to assess the potential risks to fish eating, terrestrial animals (e.g., kingfishers, mink) that may eat contaminated fish from waters near the PGDP. The focus of the evaluation was on PCBs and metals in Little Bayou and Big Bayou creeks. The average concentrations of most metals in fish were similar to reference site fish values, see Tables 8.8 and 8.9. Only copper, selenium, and uranium were clearly elevated at some sites in comparison with reference values. PCB concentrations were substantially higher in Little Bayou Creek fish, averaging 100 to 1000 fold higher than mean concentrations in reference fish. PCBs were also elevated in Big Bayou Creek fish, but levels were much lower than those typical of Little Bayou Creek fish. When contaminant concentrations in whole fish were compared to common wildlife dietary benchmarks, PCBs stood out as the contaminant of most potential ecological concern for fish eating birds and mammals.

Table 8.8. Mean (\pm SE) concentrations ($\mu\text{g/g}$, wet wt.) of various analytes in compositized longear sunfish (*Lepomis auritus*) samples collected from stream sites near the PGDP and reference streams, May 1997.

Analytes	Little Bayou Creek sites ^a			Big Bayou Creek site ^a		Massac Creek (reference site) ^a
	Outfall 010	LUK 9.0	LUK 7.2	LUK 4.3	BBK 9.1	
PCBs, total	2.12 \pm 0.13	3.59 \pm 0.10	1.74 \pm 0.08	1.23 \pm 0.06	0.52 \pm 0.04	< 0.003
Antimony	--	--	< 0.02	--	< 0.02	< 0.02
Arsenic	--	--	< 0.22	--	< 0.19	< 0.20
Beryllium	--	--	< 0.02	--	< 0.02	< 0.02
Cadmium	--	--	0.03 \pm 0.01 ^b	--	0.02 \pm 0.0 ^c	0.03 \pm 0.00
Chromium	--	--	0.30 \pm 0.01	--	0.55 \pm 0.09	0.58 \pm 0.13
Copper	--	--	0.56 \pm 0.03	--	1.07 \pm 0.32	0.60 \pm 0.10
Lead	--	--	0.20 \pm 0.02	--	0.13 \pm 0.02	0.13 \pm 0.03
Mercury	--	--	0.03 \pm 0.00	--	0.05 \pm 0.00	0.04 \pm 0.00
Nickel	--	--	0.39 \pm 0.03	--	0.72 \pm 0.07	0.49 \pm 0.02
Selenium	--	--	0.96 \pm 0.03	--	0.70 \pm 0.09	0.85 \pm 0.08
Silver	--	--	0.02 \pm 0.00 ^b	--	0.02 \pm 0.00 ^b	0.03 \pm 0.00 ^c
Thallium	--	--	< 0.02	--	0.02 \pm 0.00 ^b	0.02 \pm 0.00 ^b
Uranium	--	--	0.19 \pm 0.02	--	0.09 \pm 0.02	< 0.02
Zinc	--	--	17 \pm 0	--	21 \pm 2	22 \pm 1

^aLUK = Little Bayou Creek kilometer; BBK = Big Bayou Creek kilometer; MAK = Massac Creek kilometer

^b2 of 3 values below the detection limit

^c1 of 3 values below the detection limit. Undetected values were used to calculate the means where at least one detected value was reported. N=3 composite samples at each site except outfall 010 (N=2).

Table 8.9. Mean (\pm SE) concentrations ($\mu\text{g/g}$, wet wt.), of various analytes in composited stoneroller (*Campostoma anomalam*) samples collected from stream sites near the PGDP and reference streams, May 1997.

Analytes	PGDP Sites ^a		Massac Creek (Reference site)
	LUK 7.2	BBK 9.1	
PCBs, total	2.32 \pm 0.19	0.74 \pm 0.03	< 0.003
Antimony	< 0.02	< 0.02	< 0.02
Arsenic	0.16 \pm 0.01 ^b	< 0.20	0.44 \pm 0.12
Beryllium	< 0.02	< 0.02	0.02 \pm 0.00
Cadmium	0.04 \pm 0.01	0.02 \pm 0.00	0.04 \pm 0.01
Chromium	0.68 \pm 0.03	0.91 \pm 0.40	1.09 \pm 0.13
Copper	1.30 \pm 0	2.7 \pm 0.12	1.33 \pm 0.09
Lead	0.21 \pm 0.01	0.12 \pm 0.01	0.60 \pm 0.02
Mercury	0.03 \pm 0.00	0.05 \pm 0.01	0.03 \pm 0.00
Nickel	0.41 \pm 0.01	0.47 \pm 0.02	0.74 \pm 0.02
Selenium	0.92 \pm 0.04	1.13 \pm 0.03	0.57 \pm 0.02
Silver	0.02 \pm 0.00 ^c	0.05 \pm 0.00	0.02 \pm 0.00
Thallium	0.02 \pm 0.00 ^c	< 0.02	< 0.02
Uranium	0.77 \pm 0.03	0.24 \pm 0.02	0.05 \pm 0.00
Zinc	24 \pm 1	35 \pm 3	23 \pm 1

^aLUK = Little Bayou Creek kilometer; BBK = Big Bayou Creek kilometer; MAK = Massac Creek kilometer.

^b2 of 3 values below the detection limit

^c1 of 3 values below the detection limit. Undetected values were used to calculate the means where at least one detected value was reported.

Ecological Monitoring

Fish community monitoring

The fish communities of streams bordering PGDP are assessed by sampling three sites in Big Bayou Creek, one site in Little Bayou Creek, see Figure 8.3, and at one offsite reference station (Massac Creek) during spring and fall. The sampling consists of isolating a 100-m section of stream with nets and using electrofishers to capture all fish within the nets. These fish are then identified to species, measured for length and weight, and returned alive to the stream. The resulting data can indicate impacts of plant

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operations by following changes in total number of species, types of species present, and numbers of individual species.

Data on the fish communities gathered during 1997 for Big Bayou Creek and Little Bayou Creek downstream of PGDP were compared to data from reference sites located on Big Bayou Creek above PGDP and on Massac Creek. These comparisons indicated a slight but noticeable degradation in the communities downstream of PGDP, see Figure 8.5. Effects on the fish community were greatest just downstream from PGDP at BBK 10.0. The fish community at this site had a low number of species compared to the reference site at Massac Creek. However, slight improvements of the fish community at BBK 10.0 were noted in 1997; an additional fish species considered sensitive to stress was found for the first time (spotted sucker) and more species of fish that eat stream insects (e.g., slough darter) were collected. The lower number of species, compared with reference sites, may be a result of thermal impacts associated with outfalls. Although the temperatures may not be lethal, they could produce avoidance of the areas of Big Bayou Creek near the plant outfalls. Overall the fish community at BBK 10.0 has demonstrated shortcomings in several evaluation metrics, but has some indications of recent improvements.

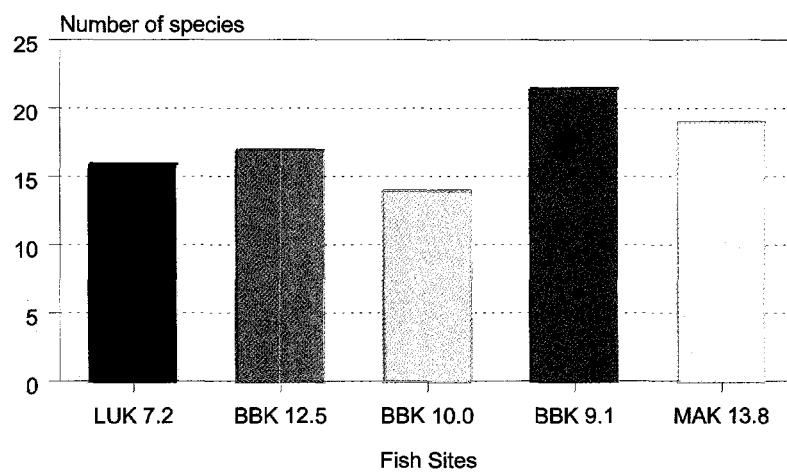


Figure 8.5 Fish Community Comparisons
(Note: LUK= Little Bayou, BBK= Big Bayou, MAK = Massac)

Downstream in Big Bayou Creek, the fish community at BBK 9.1 showed less impact than at BBK 10.0 and less impact than earlier sampling at this site. The number of fish species was very high, actually surpassing the level at Massac Creek (MAK 13.8), see Figure 8.5. The number of suckers and abundance of fish that eat stream insects also increased compared with 1996 samples. These trends indicate a lessening of impacts on recruitment success for the fish community at BBK 9.1.

The fish community in Little Bayou Creek at LUK 7.2 was similar to that at the BBK 12.5 reference site. The number of species was similar to those of the reference (BBK 12.5) site, see Figure 8.5, and has rebounded substantially from a low point in fall 1994. Generally, the conditions at LUK 7.2 indicate only minor impacts associated with PGDP operations, but recent declines in fish densities should be closely monitored as it could be indicative of more substantial long-term impacts.

Monitoring of the fish communities associated with PGDP streams indicated some depressed conditions but did not specifically identify causative agents. The impacts were limited to sites closest to the plant, which suggests that PGDP discharges (e.g., high temperatures or increases in sedimentation) may be the

cause. It is also possible that the low species richness and lack of sensitive species may reflect degraded habitat conditions or be a common characteristic of the Big Bayou Creek watershed.

Terrestrial Wildlife

Deer

Because DOE retains responsibility for historic releases, the deer population is sampled annually to look for any increases in inorganic elements that might be attributed to past plant practices. There were eight deer harvested from the West Kentucky Wildlife Management Area and two deer harvested from the Pennyriile State Forest to serve as background samples. Neither PCBs in fat nor technetium (^{99}Tc) in thyroid were detectable in any of the ten deer harvested. Arsenic and mercury were also nondetectable in the samples. Tables 8.10 and 8.11 show the analytical results for inorganics in liver and muscle tissue, respectively. When compared to 1995 and 1996 data, no unusual levels of inorganic elements were identified.

In summary, there were no unusual finds in the 1997 deer data. When comparing Paducah Site deer data to the background deer data, the results were not substantially greater. The data will be assessed in future sampling events to identify any potential trends.

Small Mammals Study

In November of 1996, AIP personnel analyzed tissue from a coyote killed by a deer hunter on the WKWMA and a bobcat killed by a vehicle north of Highway 358. The results of the analysis found the coyote nondetect for PCBs while the bobcat data indicated PCB present at 2.2mg/kg. In May 1997, during an AIP program to band hawks and draw blood for PCB analysis, one blood sample was found with 0.65 ppm PCB. This data indicated that red-tailed hawks and bobcats were exposed to PCBs on or near PGDP causing concern that bioaccumulation was occurring in predators.

In an effort to quantify PCBs and heavy metal exposure of small mammals inhabiting areas surrounding the PGDP and to better understand the potential movement of contaminants through the foodchain, Clemson University was contracted to perform a study to determine residue levels of these compounds in white-footed mice (*Peromyscus leucopus*) and marsh rice rats (*Oryzomys palustris*). Results of the study were reported in *Polychlorinated Biphenyl and Metal Exposure of Small Mammals at the Paducah Gaseous Diffusion Plant, McCracken County, Kentucky* (McMurry 1997). White-footed mice and rice rats represent a plentiful prey item resource for many predators including red-tailed hawks and bobcats. While white-footed mice are quite common in most local habitats, rice rats are concentrated on or near lowlands and creek bottoms. Since much of the contamination at PGDP is thought to be centered around watersheds, it was felt that these organisms would be suitable sentinels for PCB and metal exposure.

Table 8.10 Analysis of deer muscle tissue for 1997

Deer	Inorganic $\mu\text{g/g}$												
	Al	Ba	Cd	Cr	Cu	Fe	Mg	Mn	P	Se	Ag	V	Zn
1	ND ^a	0.1	ND	ND	1.7	37.0	254	ND	2160	ND	ND	ND	12.5
2	2.6	ND	0.2	0.4	1.3	21.8	239	0.2	2030	ND	ND	ND	14.4
3	ND	ND	ND	0.5	1.6	34.2	252	0.3	2150	ND	ND	0.4	13.4
4	ND	ND	ND	0.3	1.3	27.6	243	0.2	2040	ND	ND	ND	12.9
5	ND	ND	ND	0.4	1.4	35.4	254	ND	2140	ND	ND	ND	11.2
6	ND	ND	ND	0.4	1.3	39.1	252	ND	2140	ND	5.4	0.3	33.0
7	ND	ND	ND	ND	1.7	31.7	284	0.1	2150	ND	ND	ND	15.1
8	ND	ND	ND	ND	1.0	33.6	256	0.2	2350	ND	ND	ND	12.3
9 ^b	ND	ND	ND	ND	1.5	38.0	269	0.2	2350	ND	ND	ND	15.4
<i>Background Deer</i>													
10	ND	ND	ND	0.4	1.5	27.9	259	ND	2200	ND	24.9	ND	16.7
11	ND	ND	0.3	0.39	1.7	33.5	277	0.2	2330	ND	1.9	ND	17.1

^a Not Detectable

^b Duplicate

Table 8.11 Analysis of deer liver tissue for 1997

Deer	Inorganic $\mu\text{g/g}$												
	Al	Ba	Cd	Cr	Cu	Fe	Mg	Mn	P	Se	Ag	V	Zn
1	ND ^a	ND	0.3	0.3	36.3	47.8	166	3.7	3360	ND	ND	ND	36.9
2	ND	ND	0.2	0.4	53.7	92.4	168	4.4	3300	ND	ND	ND	36.7
3	ND	ND	0.4	0.4	56.3	61.1	175	4.4	3470	ND	6.1	ND	40.6
4	3.2	ND	ND	0.5	52.1	76.6	158	4.1	3160	ND	ND	ND	37.6
5	ND	ND	ND	ND	46.9	75.3	150	3.9	3070	ND	ND	ND	28.9
6	ND	0.1	ND	0.3	5.3	578	123	0.8	1980	ND	ND	0.2	20.9
7	ND	ND	ND	ND	87.2	48.3	169	4.8	3350	ND	ND	ND	38.7
8	ND	0.3	ND	ND	18.1	148	230	3.7	3500	ND	ND	ND	21.4
9 ^b	ND	ND	ND	ND	39.2	51.1	159	4.3	3580	ND	ND	ND	37.6
<i>Background Deer</i>													
10	ND	ND	0.3	0.5	148	69	187	4.7	3740	ND	ND	ND	44.6
11	ND	ND	0.3	0.4	54.5	172	154	3.8	3070	ND	ND	ND	44.5

^a Not Detectable^b Duplicate

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Residue analysis of white-footed mouse and rice rat tissues collected from areas surrounding PGDP indicates that exposure to heavy metals and PCBs is occurring. While heavy metal concentrations in kidneys were higher at the reference site than PGDP for several metals, arsenic, cadmium, chromium, and lead appeared to be slightly to moderately elevated in PGDP animals. These metals have been shown to be toxic to a wide variety of organisms although, residue levels below acutely lethal levels are difficult to interpret as to their significance. Species to species variability, natural stressors, and synergism with other contaminants make tissue residue levels difficult to classify as either toxic or non-toxic and without effects data, relevance of these findings is unclear.

PCBs were present in some animals from all sites sampled. However, reference white-footed mice contained very small quantities of only two congeners. Conversely, PGDP white-footed mice and rice rats contained detectable quantities of several congeners, specifically the more highly chlorinated compounds which would be most likely to persist in the environment and potentially more toxic. Total selected highly chlorinated PCBs from each site showed that animals from the north-south diversion ditch area and an area near Little Bayou Creek just east of the plant contained the highest concentrations of PCBs. Table 8.12 shows the concentration of metals in the kidney tissue while Table 8.13 shows the concentration of PCB congeners in liver tissue. Figure 8.6 shows live traps being set for small mammal collection.

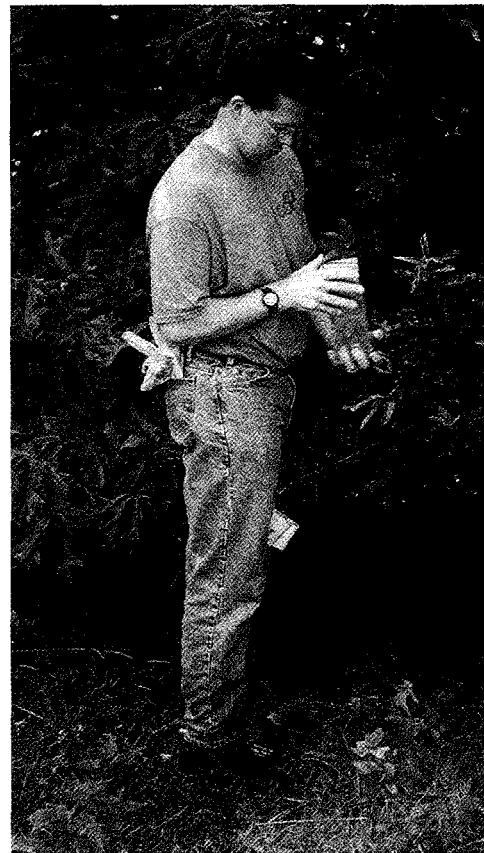


Figure 8.6 Setting live traps

**Table 8.12 Average concentrations of metals in kidney tissue
(ppm)**

Metal	Reference Site	White-footed Mice	Marsh Rice Rats
Arsenic	0.098	0.084	0.082
Antimony	2.739	0.267	0.212
Barium	12.388	9.226	5.85
Beryllium	0	0	0
Cadmium	0	0.562	0.893
Chromium	2.674	1.429	0.891
Copper	11.119	13.492	11.195
Lead	3.974	5.570	1.929
Nickel	1.128	0.938	1.316
Titanium	4.752	0.777	0
Silver	0	0	0
Aluminum	103.652	70.341	51.324
Iron	247.510	243.142	316.276
Number of Samples	8	28	19

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**Table 8.13 Average concentrations of PCB congeners in liver tissue
(ppb)**

PCB Congener	Reference Site	White-footed Mice	Marsh Rice Rats
5	0	0	0.43
12	0	1.72	1.88
28	0	0	0
44	0	0	0
66	0	0.49	0
110	0	0	0
118	0	2.55	2.97
153	0.61	34.45	24.12
138	0.20	8.75	9.62
180	0	70.49	35.58
170	0	27.33	3.82
Number of samples	8	23	19
Total PCB	0.81	143.57	74.24

9. Groundwater

Abstract

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

Introduction

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

When off-site contamination from the Paducah Site was discovered in 1988, the EPA and DOE entered into an Administrative Consent Order (ACO). DOE provided an alternate water supply to affected residences. Under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), DOE was required to determine the nature and extent of off-site contamination through sampling of potentially affected wells and a comprehensive site investigation.

The CERCLA/ACO site investigation, completed in 1991, determined off-site contaminants in the regional gravel aquifer (RGA) to be trichloroethylene (TCE), an industrial degreasing solvent, and technetium (^{99}Tc), a fission by-product contained in nuclear power reactor returns that were brought on-site several years ago for re-enrichment. Such reactor returns are no longer enriched. Known or suspected sources of TCE include burial grounds, test areas, and other operating facilities. Likely ^{99}Tc sources are spills and leaks of contaminated TCE and leachate derived from contaminated scrap metal.

Investigations into the onsite source areas of TCE at the Paducah Site are ongoing. TCE, a common degreasing agent, is considered a dense non-aqueous phase liquid (DNAPL). DNAPLs typically have low solubilities in water and sink to the bottom of aquifers or come to rest upon a less permeable layer within an aquifer, forming pools. These DNAPL pools form a continuing source to dissolved-phase pollution (plumes) that are migrating offsite toward the Ohio River. DNAPL pools are extremely difficult to clean up and currently only the highest concentrations of dissolved TCE are controlled by pump-and-treat systems at Paducah. The pump-and-treat system installed northwest of the plant also controls the highest concentrations of dissolved ^{99}Tc migrating offsite. Continued groundwater monitoring serves to identify the extent of contamination, predict the possible fate of the contaminants, and determine the movement of groundwater near the plant.

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Groundwater monitoring at Paducah complies with one or more federal or state regulations and permit conditions and includes perimeter exit-pathway monitoring and off-site water well monitoring. A more detailed description of groundwater monitoring is under "Groundwater Monitoring Program." Figures 9.1 through 9.6 show the locations of all wells sampled during 1997. Analytical results from the sampling described in this section are available upon request from the Public Affairs Group.

Groundwater Hydrology

A portion of rainwater accumulates as groundwater by soaking into the ground, infiltrating porous soil and rock. The accumulation of groundwater in pore spaces of sediments creates a source of useable water an aquifer, see Figure 9.7. Water from the surface moving down through the soil makes its way by percolating downward through the pore spaces between soil grains, see Figure 9.8. The smaller the pore spaces, the slower the flow of water through the sediment. The physical property that describes the ease with which water can move through the pore spaces and fractures in a material is called hydraulic conductivity, or permeability. Permeability is determined not only by the volume and size of the pore spaces but also by how well the pore spaces are connected. Aquifers are found in permeable sediments (such as sand and gravel) and rocks (such as sandstone and fractured limestone). Less permeable sediments (such as clay) and rocks (such as shale and

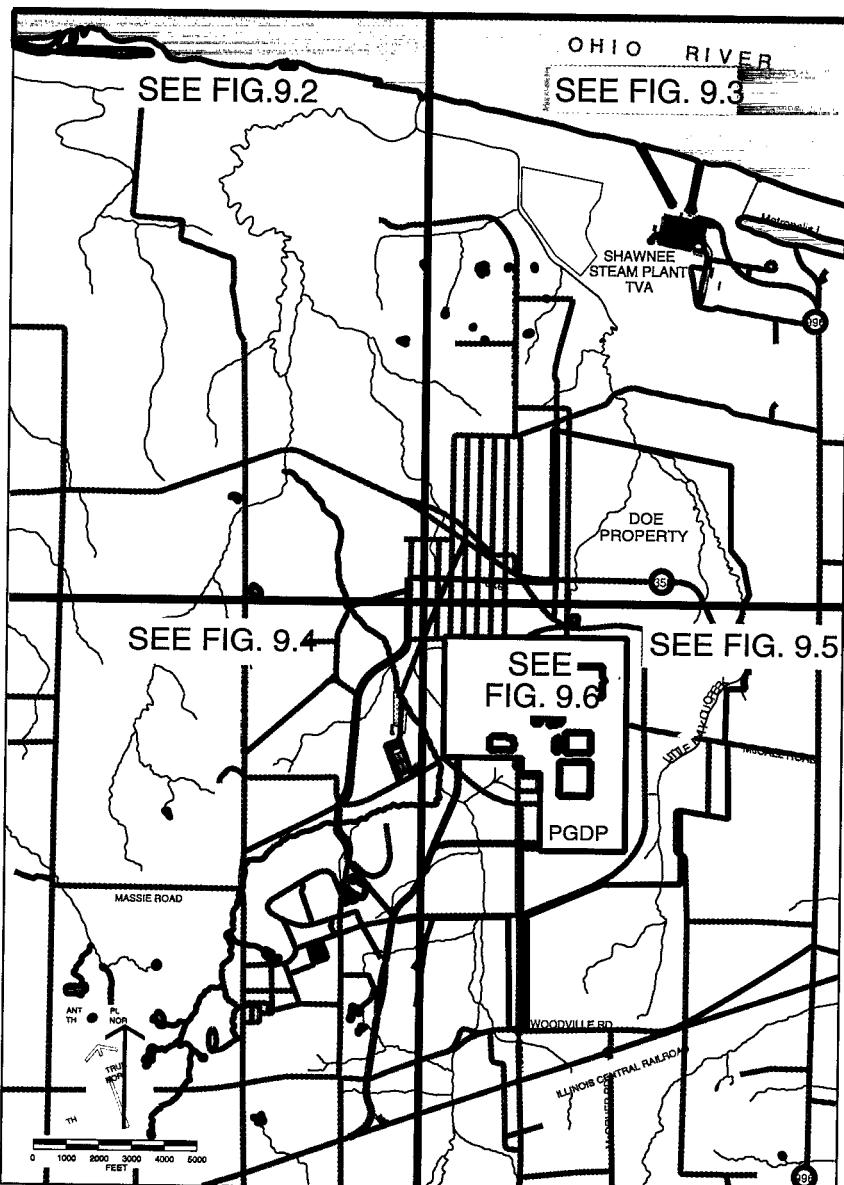


Figure 9.1 Wells sampled at the Paducah Site in 1997 (by sectors).

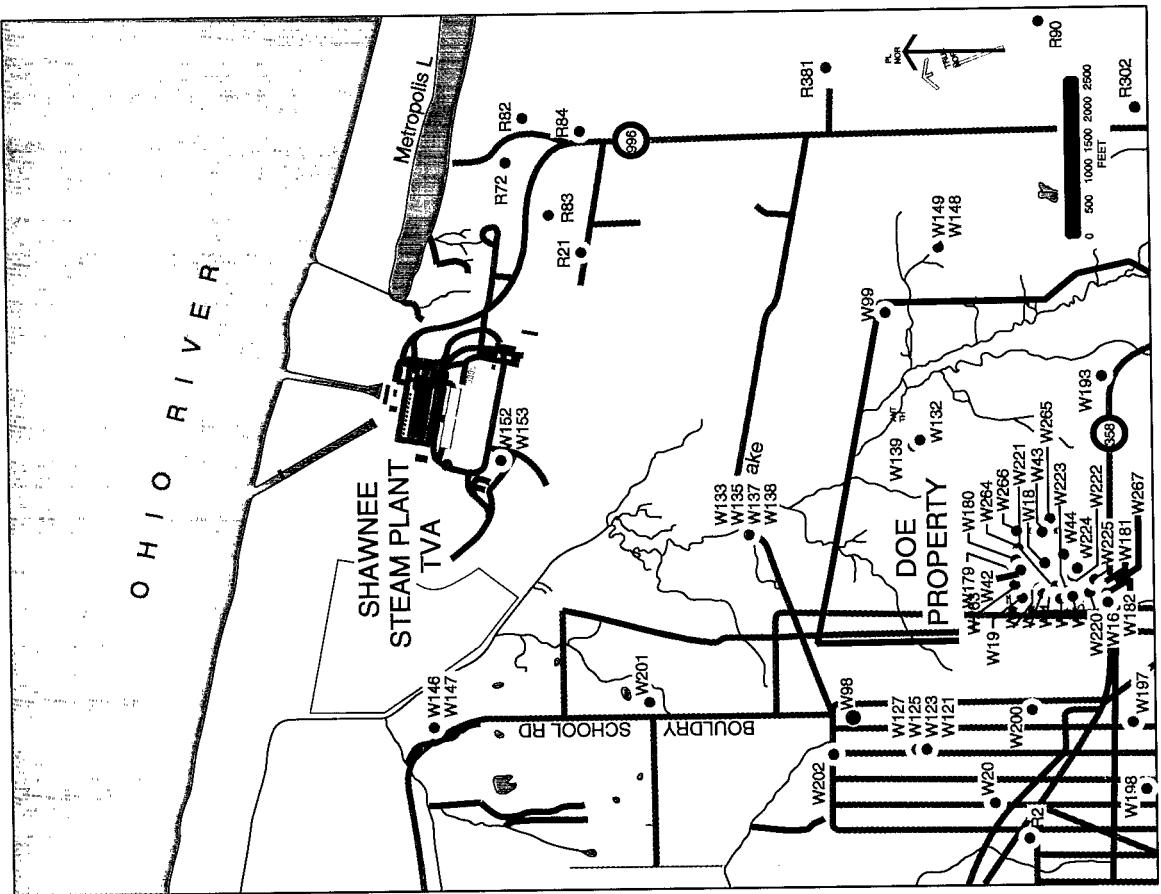


Figure 9.3 Wells sampled - northeast sector.

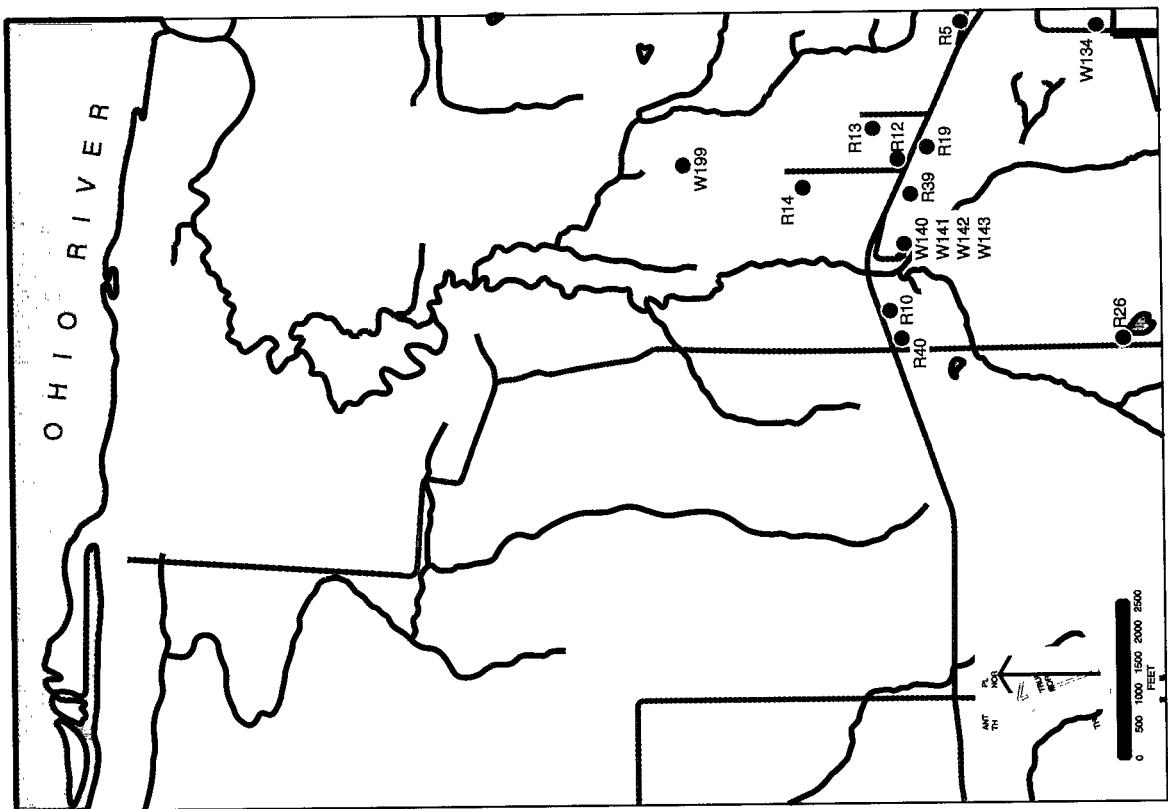


Figure 9.2 Wells sampled - northwest sector.

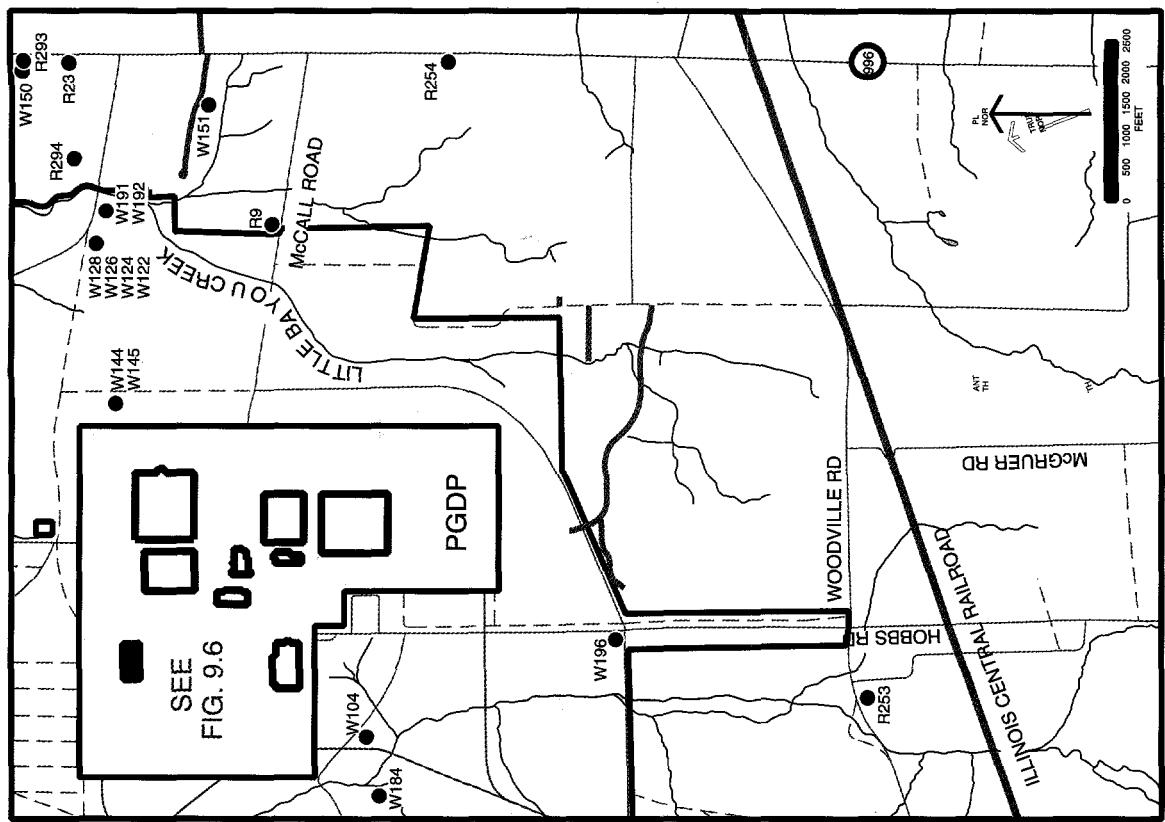


Figure 9.5 Wells sampled - southeast sector.

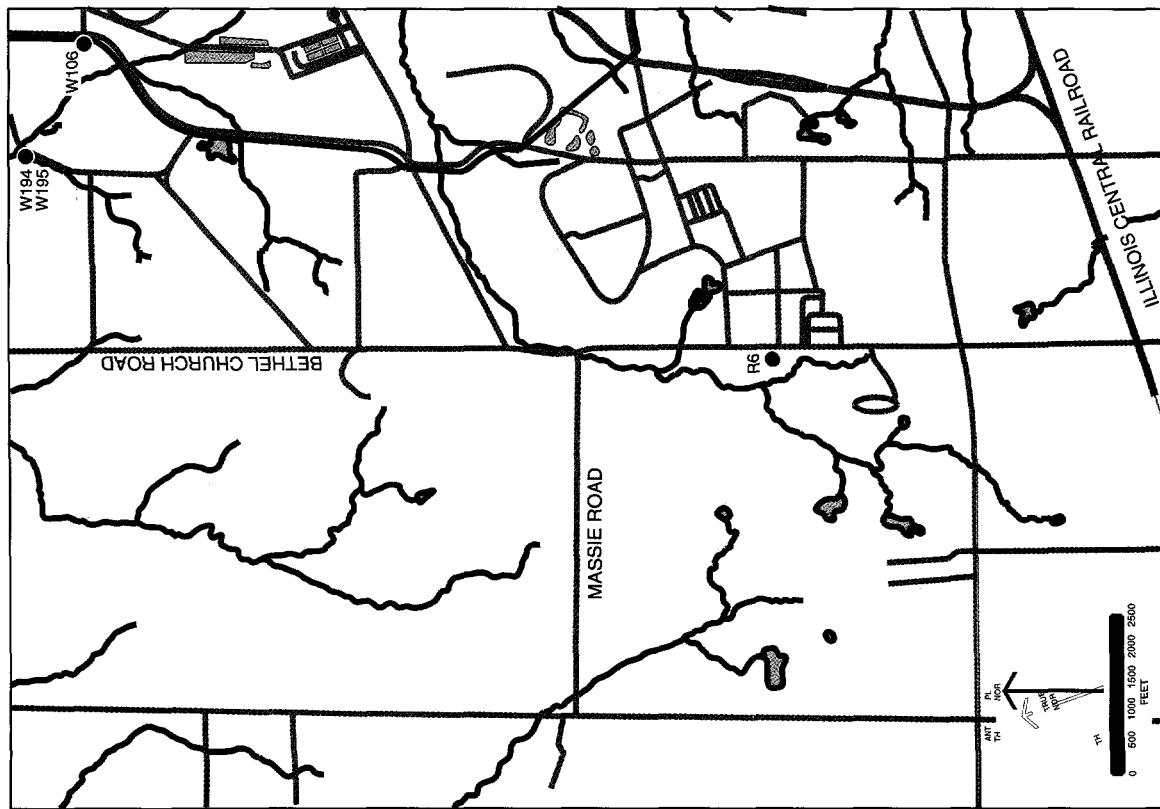


Figure 9.4 Wells sampled - southwest sector.

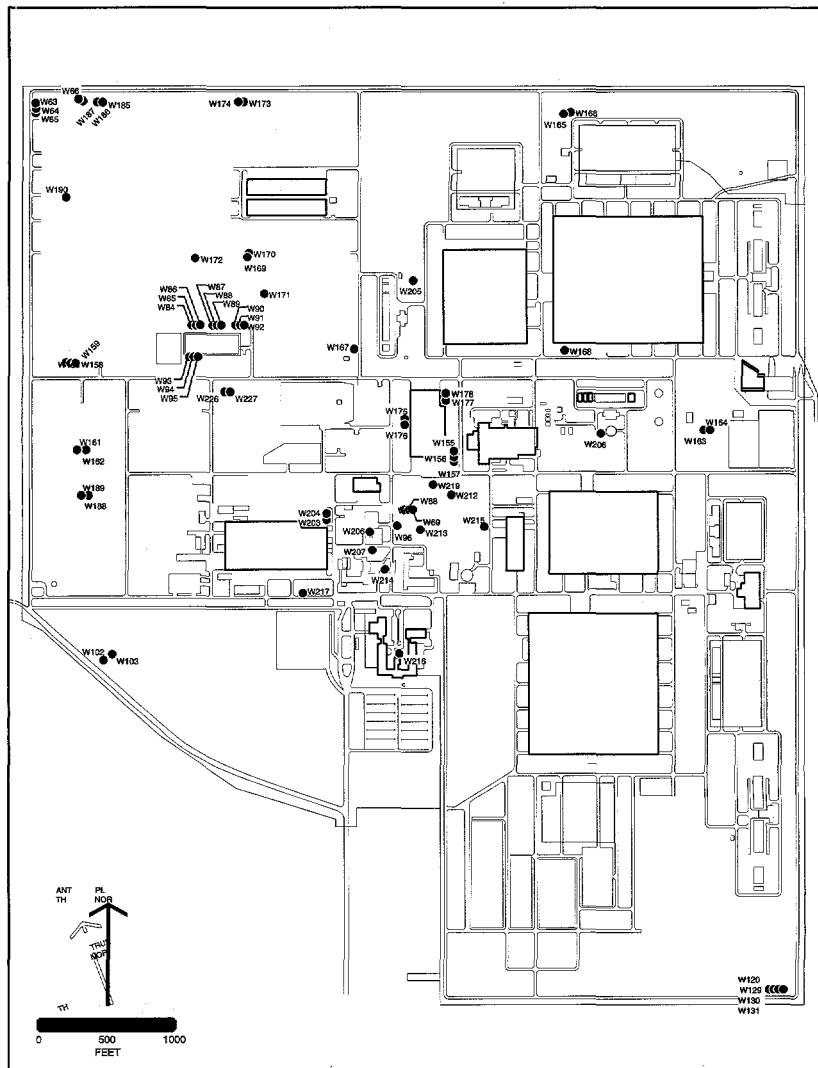


Figure 9.6 Wells sampled - plant site.

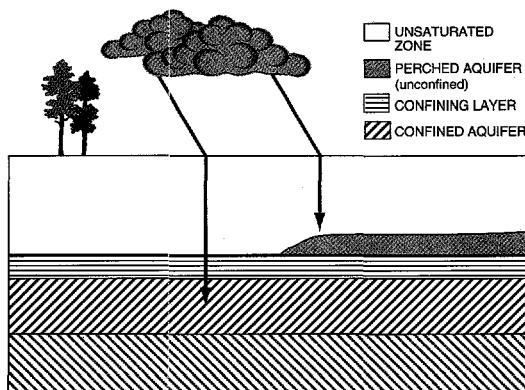


Figure 9.7 Typical path for rainwater accumulation as groundwater.

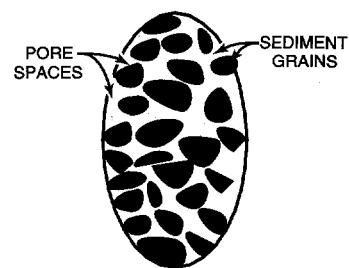


Figure 9.8 Pore spaces in soil.

dense limestone) make up aquitards that restrict groundwater movement. The boundary between the unsaturated and the saturated zones is known as the water table. This boundary usually, but not always, gently mirrors the surface topography, rising above natural exits such as springs, swamps, and beds of streams and rivers, where groundwater is discharged to the surface. Groundwater movement is determined by differences in hydraulic head (a function of the energy associated with the water's elevation above sea level and the pressures exerted on it by surrounding water). Water will rise in a well casing in response to the pressure of the water surrounding the well's screened zone. The depth to water in the well is measured and the elevation calculated to determine the hydraulic head of the water in the monitored zone, see Figure 9.9. The hydraulic gradient measures the difference in hydraulic head over a specified distance. By comparing the water levels in adjacent wells screened in the same zone, a horizontal hydraulic gradient can be determined and the lateral direction of groundwater flow can be predicted. Only wells screened in the same zones are considered when determining the horizontal gradient. Wells screened above and below an aquitard can also have different hydraulic heads, thus defining a vertical gradient. If the water levels in deeper wells are lower than those in shallower wells, the vertical component of flow is downward.

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

Groundwater aquifers are one of the primary pathways by which potentially hazardous substances can spread through the environment. Substances placed in the soil may migrate downward due to gravity or be dissolved in rainwater, which moves them downward through the unsaturated zone into the aquifer. The contaminated water then flows downgradient toward the discharge point. Monitoring wells are used extensively to assess the effect of plant operations on nearby groundwater quality. Wells positioned to sample groundwater flowing away from a site are called downgradient wells, and wells placed to sample groundwater before it flows under a site are called upgradient wells. Any contamination of the downgradient wells not present in the upgradient wells at a site may be assumed to be a product of that site. Wells can be drilled to various depths in the saturated zone and be screened to monitor the recharge area above the aquifer, different horizons within the aquifer, or water-bearing zones below the aquifer.

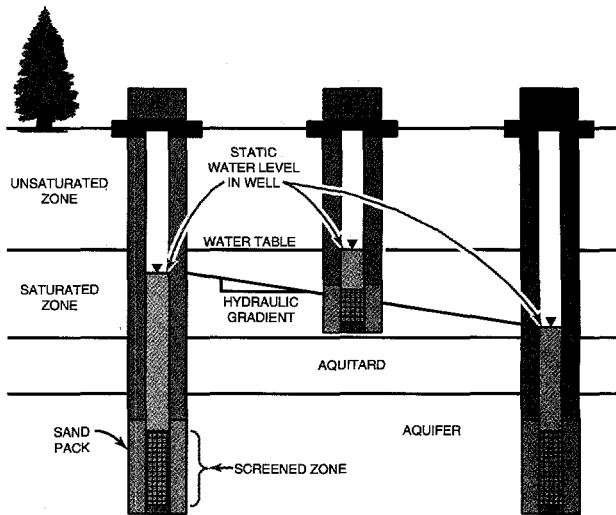


Figure 9.9 Monitoring well construction showing relationship between screened zone and water level in wells where limited flow through the aquitard is downward and flow in the aquifer is to the right.

Vertical and horizontal groundwater flow directions are determined by the permeability and continuity of geologic strata in addition to hydraulic head. To effectively monitor the movement of groundwater and any hazardous constituents it may contain, hydrogeologists at the Paducah Site have undertaken many detailed studies of the geology of strata beneath the site.

Geologic and Hydrogeologic Setting

The Paducah Site, located in the Jackson Purchase region of western Kentucky, lies within the northern tip of the Mississippi Embayment portion of the Gulf Coastal Plain Province. The Mississippi Embayment is a large sedimentary trough oriented nearly north-south that received sediments during the Cretaceous and Tertiary geologic time periods. Figure 9.10 is a schematic cross-section illustrating regional stratigraphic relationships in the vicinity of the Paducah Site.

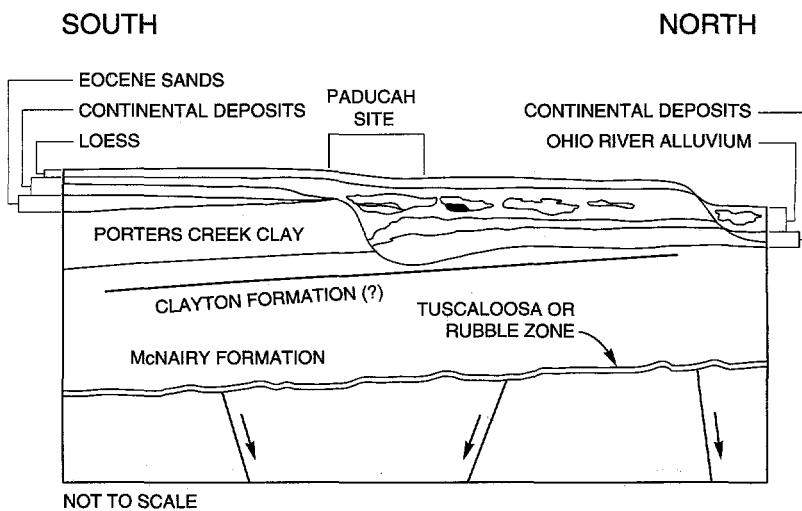


Figure 9.10 North-south section showing regional stratigraphic relationships.

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

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

The next feature in the geologic history at the Paducah Site is a Pleistocene-age river valley occupying approximately the same position as the present day Ohio and Tennessee river valleys. In forming the valley, braided stream channels of the ancestral Tennessee River, and possibly several "feeder" streams, eroded any sediments deposited after the Paleocene Porters Creek Clay and before the Pleistocene. The river system also eroded portions of the Porters Creek Clay and the McNairy/Clayton Formation and cut a prominent terrace in the Porters Creek Clay at the south end of the plant. The sediments deposited on this erosional surface are termed continental deposits. The lower portion of the continental deposits consists of approximately 9 m (30 ft) of stream gravel and sand.

Over time, sediments from the retreating glaciers dammed the river valley, causing the formation of a lake. Silts and clays with thin zones of sand and occasional gravel were deposited in the lake, forming the

upper portion of the continental deposits. These deposits range from approximately 1.5 to 17 m (5 to 55 ft) thick.

Finally, loess, a wind-blown silt, overlies the continental deposits throughout the site. Thickness of loess deposits varies from approximately 1.5 to 8 m (5 to 25 ft), averaging approximately 4.6 m (15 ft).

The local groundwater flow system at the Paducah Site contains four major components: the McNairy flow system, the regional gravel aquifer (RGA), the upper continental recharge system (UCRS), and the terrace gravels.

- The McNairy flow system consists of interbedded and interlensing sand, silt, and clay of the McNairy Formation. Sand facies account for 40 to 50% of the total formation thickness of approximately 69 m (225 ft).
- The RGA consists of sand and gravel facies in the lower continental deposits, gravel and coarse sand portions of the upper McNairy that are directly adjacent to the lower continental deposits, coarse-grained sediments at the base of the upper continental deposits, and alluvium adjacent to the Ohio River. These deposits have an average thickness of 9 m (30 ft) and range up to 15 m (50 ft) along an axis that trends east-west through the site. The RGA is the uppermost and primary aquifer, formerly used by private residences north of the Paducah Site.
- The UCRS consists mainly of clayey silt with interbedded sand and gravel in the upper continental deposits. The system is so named because of its characteristic recharge to the RGA.
- The terrace gravels consist of shallow Pliocene gravel deposits in the southern portion of the plant site. These deposits usually lack sufficient thickness and saturation to constitute an aquifer but may be an important source of groundwater recharge to the RGA.

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

Uses of Groundwater in the Vicinity

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

Both groundwater and surface water sources have been used for water supply to residents and industries in the plant area. Wells in the area are screened at depths ranging from 4.6 to 75 m (15 to 245 ft). Most of these wells are believed to be screened in the RGA. The Paducah Site continues to provide municipal water to all residents within the area of groundwater contamination from the site. These residents' wells have been turned over to the LMES for sampling. Residential wells that are no longer sampled have been capped and locked.

Groundwater Monitoring Program

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

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

These objectives are outlined in three documents relating to groundwater monitoring: *Paducah Gaseous Diffusion Plant Groundwater Protection Program Management Plan* (Miller 1997) and the *Environmental Monitoring Plan* (LMES 1995).

The *Paducah Gaseous Diffusion Plant Groundwater Protection Program Management Plan* identifies specific responsibilities, assigns responsibility to various entities within the plant, and coordinates Environmental Restoration and Environmental Management initiatives.

Groundwater Monitoring

Scheduled sampling continues for more than 150 monitoring wells, residential wells, and Tennessee Valley Authority wells in accordance with DOE orders and federal, state, and local requirements. Well sampling includes several different monitoring programs, which are described below.

RCRA Interim Status and Permit Monitoring Programs

At present, the only hazardous waste facility at the Paducah Site that requires groundwater monitoring is the C-404 landfill. This landfill was operated until 1986, when hazardous waste was discovered at the facility. The landfill was covered with a Resource Conservation and Recovery Act (RCRA)-compliant clay cap and was certified closed as a hazardous waste landfill in 1987. The landfill is now monitored under post-closure monitoring requirements.

According to EPA Hazardous Waste Permit KY8-890-008-982, 14 wells, MWs 84-95, 226, and 227, monitor groundwater quality of the UCFS and the underlying RGA during the required post-closure care. Monitoring had previously been required on a quarterly basis. Monitoring at the landfill was changed in 1994 from assessment monitoring to detection monitoring, which is required semiannually. In

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accordance with permit condition II.J.7.3.i, the Director of the Kentucky Division of Waste Management was notified May 10, 1996, in writing, of a statistically significant increase of ^{99}Tc in MW 84. Compliance monitoring was then initiated for the radionuclides ^{99}Tc , U-234, U-235, and U-238 and has continued through calendar year 1997.

State Solid Waste Disposal Regulations

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

The groundwater monitoring system for the above mentioned facilities consists of (3) upgradient and (10) downgradient wells. The system is designed to monitor both the upper and lower portions of the RGA. Upgradient wells are recognized as MW 181, MW 220, and MW 267 while downgradient wells are recognized as MW 179, MW 221 thru MW 225, and MW 263 thru MW 266. MW 225 is monitored for static water level only. The monitoring wells are sampled quarterly and in accordance with 401 Kentucky Administrative Regulations (KAR) 48:300. The analytes are dictated by a KDWM approved solid waste landfill permit modification.

A new solid waste landfill has been constructed at the Paducah Site and is identified as the C-746-U Contained Landfill. Construction was completed in 1996, but active operation was not initiated until 1997. Solid waste regulations require groundwater characterization of the upper most aquifer down to and including the lowest aquifer that may be affected by the facility. The chemical description shall include two (2) samples of groundwater from the site before waste placement for the parameters listed in 401 KAR 48:300 Section 10.

The groundwater monitoring system for this facility is described in Section 25 of the landfill's Technical Application for a solid waste landfill permit. The groundwater monitoring network consists of (10) wells located in five two-well clusters. One well cluster (MW 276, MW 277) is located hydraulically upgradient of the facility and four well clusters (MW 268 thru MW 275) are located hydraulically downgradient. The system is designed to monitor both the upper and lower portions of the RGA.

Groundwater characterization data for the C-746-U Contained Landfill facility was submitted to the KDWM during December, 1995. Samples were collected during January 1995 (low-water table conditions) and May 1995 (high-water table conditions) with select parameters also collected during September 1995 as part of the low-water table conditions.

Five piezometers installed to establish the presence or absence of a water table at the C-746-U landfill were abandoned in 1997. These piezometers established that a shallow water table was not present beneath the disposal cells. Additionally, the KDWM required sampling of these piezometers to establish

a baseline for TCE and ^{99}Tc . These piezometers had served their intended purpose and were no longer required. Abandonment was completed by removing casing and screens, reaming the hole and grouting it to the surface with high solids bentonite grout.

CERCLA/ACO Monitoring (Off-Site Wells)

The ACO between DOE and EPA under CERCLA legislation requires monthly sampling of residential wells potentially affected by the contaminant plume (EPA, 1988). Currently, only four residential wells (R2, R5, R294, and R302) meet this criteria. Additionally, MW 66 is also required to be sampled on a monthly basis. All monthly sampled wells were analyzed for gross alpha and beta, TCE and ^{99}Tc . As stated previously, the hydrologic unit in which residential wells are screened is uncertain; however, most are believed to be RGA wells.

Environmental Surveillance Monitoring

Environmental surveillance monitoring is defined as perimeter exit pathway monitoring and off-site water well monitoring. Environmental surveillance monitoring is conducted in support of DOE Orders but is not regulatory driven. The groundwater monitoring requirement for each of these specific laws, regulations, and orders are addressed in the *Paducah Gaseous Diffusion Plant Groundwater Protection Program Plan Addendum to Sampling Analysis Plan* (Clausen 1996). Specific wells monitored for environmental surveillance are as follows:

- *Annual Monitoring Program*—MWs 71, 96, 106, 133, 134, 155, 156, 159, 161, 163, 168, 169, 175, 178, 180, 182, 188, 191, 192, 193, 200, 201, 203, 205, 206, and 255;
- *Quarterly Monitoring Program*—MWs 20, 63, 65, 98, 99, 124, 125, 135, 139, 145, 146, 152, 165, 166, 173, 174, 185, 186, 187, 197, 202, 256, 258, 260, 261, 262, 328, and 329.

Environmental Restoration Activities

Groundwater Integrator Unit

Recent investigations have led to the discovery of several separate groundwater plumes, which commingle and appear to contribute to one of two off-site groundwater plumes: the northwest plume and the northeast plume, see Fig. 9.11. Primary contaminants of these plumes are TCE in the northeast plume and TCE and ^{99}Tc in the northwest plume. The contaminated groundwater is grouped within a groundwater integrator unit for investigation and remediation. Groundwater is grouped this way because (1) the contamination is isolated from surface sources, (2) sources of contamination are uncertain, (3) the groundwater underlies many waste area groups (WAGs), and (4) the groundwater will be remediated independent of other solid waste management units (SWMUs), in part because of the presence of DNAPLs.

An interim action record of decision for the northwest plume was agreed upon in 1993 by the EPA, the Commonwealth of Kentucky, and DOE. The decision is proposed as a first phase of remedial action for groundwater at the site and is not intended as a final action. Operations began at the Northwest Plume

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Groundwater System in August 1995 and has continued to operate through 1997.

Interim Remedial Action Record of Decision for the Northwest Plume

The EPA approved an interim remedial action record of decision to hydraulically contain off-site migration of the northwest plume. This action is a first phase of remedial action for groundwater at the Paducah Site. Two extraction wells near a source of the northwest plume and two additional extraction wells farther north, near the centroid of the plume, were installed. Each set of extraction wells is surrounded by a monitoring well network. The network is used for monitoring groundwater quality and water levels to determine the effectiveness of the interim action. The groundwater extraction system recovers TCE- and ^{99}Tc -contaminated groundwater from the RGA northwest of the plant boundary. Water extracted from the wells is treated by air stripping for the TCE and by ion exchange to remove the ^{99}Tc before being discharged into a KPDES surface water outfall. Since beginning operations on August 28, 1995, through the end of 1997, approximately 226 million gallons of water have been treated. This has resulted in the removal of approximately 280 gallons of TCE and 0.3 curies of ^{99}Tc , based on an average flow and concentration for the year.

Long term monitoring has been conducted at the Northwest Plume over a period of 3 years. Data gathered in 1995 through 1997 suggest that the overall concentration of TCE and Tc^{99} in the majority of the wells is decreasing. This indicates that the well fields are beginning to achieve capture of the plume.

Numerical Groundwater Model Recalibration

The existing groundwater flow model for the Northwest Plume was recalibrated and evaluated during 1997. This recalibration consisted of reworking the existing site model to more closely match flow paths of the Northwest Plume currently defined by monitoring well and soil boring data. A more detailed

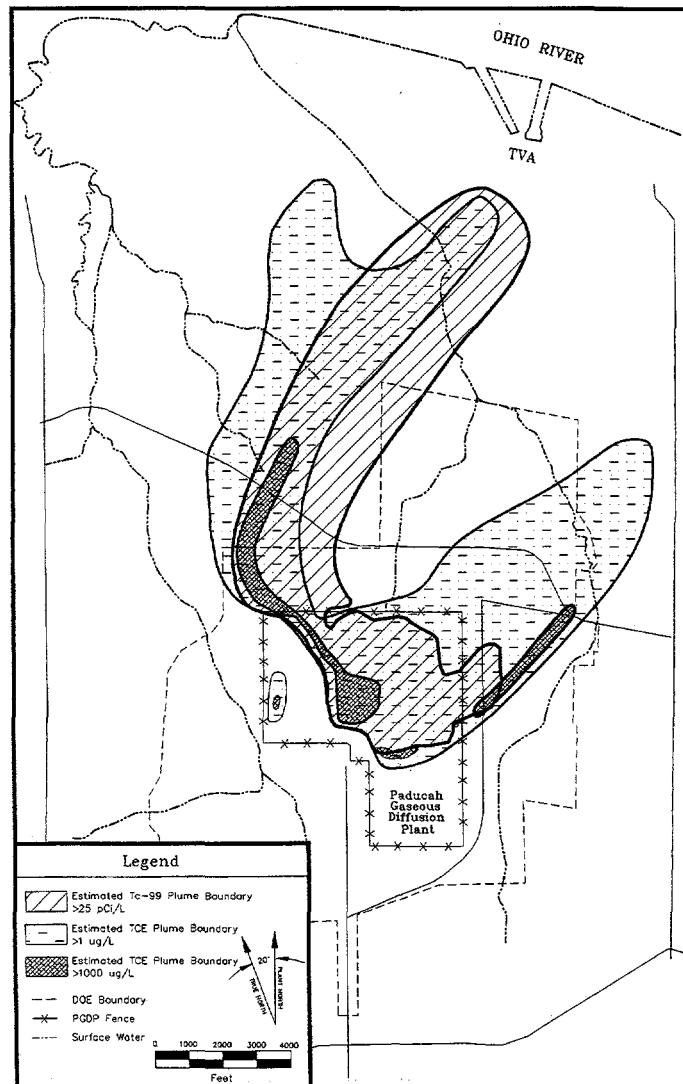


Figure 9.11 Off-site extension of groundwater plumes. (1996)

discussion of this work is documented in *Numerical Ground-Water Model Recalibration and Evaluation of the Northwest Plume Interim Remedial Action Report for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (Jacobs EM Team 1997).

Northwest Plume Interceptor System Evaluation

The Northwest Plume Interceptor System Evaluation was completed in 1997. This evaluation involved modeling the Northwest Plume with the assumption that a high conductivity zone exists along the axis of the plume's high concentration volume. This approach was then evaluated for its ability to closely match the existing plume as it is currently defined by monitoring well and soil boring data. Results of these activities are documented in *Paducah Gaseous Diffusion Plant Northwest Plume Interceptor System Evaluation*, (ORNL/TM-13333, May 1997)

Evaluation of Natural Attenuation Process for Trichloroethylene and Technetium-99

The Natural Attenuation Processes and their effects on Trichloroethylene and Technetium-99 in the Northeast and Northwest Plumes were evaluated through combined efforts of Paducah Site EMEF and Argonne National Laboratory. The Natural Attenuation Process is the process by which nature "cleans up" or works to restore itself to its original condition prior to the introduction of other things such as contamination without the aid or intervention of human remedies. This study concluded that although the Natural Attenuation Processes are active within the plumes, the rate is insufficient to utilize as a viable remedial measure for either dissolved phase plume. Detailed results of this study are provided in *Evaluation of Natural Attenuation processes for Trichloroethylene and Technetium-99 in the Northeast and Northwest Plumes at the Paducah Gaseous Diffusion Plant Paducah Kentucky, KY/EM-113*.

Evaluation of Total vs. Dissolved Metals concentrations in Northwest Plume Groundwater at Paducah Gaseous Diffusion Plant

A study of the total versus dissolved metals concentrations in the Northwest Plume was completed. Current practice is that both filtered and unfiltered samples from groundwater monitoring wells be collected and analyzed for metals which add to the expense of groundwater investigations. The unfiltered, turbid samples are more often used for completing Human Health and Environmental Risk Assessments which provide more conservative and usually more costly remedies. This study showed preliminary results that the filtered samples are the most appropriate to use based on analytical results from well samples and a study of the installation and operation of community and individual groundwater supply wells. A draft document, *Evaluation of Total vs Dissolved Metals Concentrations in Northwest Plume Groundwater at Paducah Gaseous Diffusion Plant* (Diefendorf April 1997), provides the results of this study.

Interim Action Record of Decision for the Northeast Plume

Construction for the Record of Decision approved by the EPA in June of 1995 and completed in 1996, consisted of 2 extraction wells, monitoring wells, piezometers, and facilities required to transfer the TCE-contaminated water to the C-637 Cooling Tower for treatment. This action was implemented by first completing two transects of soil borings, one in the proposed extraction well field area and one upgradient from this area. These borings were used to fill in data gaps from the Northeast Plume Investigation

completed in October of 1994, provide information required to further delineate the high concentration volume within the Northeast Plume, locate the extraction wells and associated monitoring wells and piezometers and locate an upgradient monitoring well. An aquifer step test was performed on each extraction well to provide a baseline of hydrogeologic conditions and determine each extraction well efficiency. Groundwater quality and water level information obtained from the piezometers and monitoring wells will be used to evaluate the effectiveness of the remedial action. The upgradient monitoring well will be used to detect possible ⁹⁹Tc contamination within the high concentration area of the plume before it reaches the extraction wells.

Since beginning operations on February 28, 1997, and through the end of 1997, approximately 72 million gallons of water have been treated. Based on an average concentration and flow rate since the facility started on February 28, 1997, approximately 54 gallons of TCE have been removed.

Lasagna® Demonstration (SWMU 91)

A research consortium (consisting of Monsanto, DuPont and General Electric), in conjunction with DOE, began work to demonstrate the use of electroosmosis in combination with in situ remediation zones to remediate low permeability soils. Field equipment was installed for Phase I in November 1994. Phase I of the demonstration operated between January and June 1995. Based on the success of the Phase I demonstration at SWMU 91, Phase IIA was proposed and implemented. Installation of Phase IIA was completed in July 1996 and has operated through August 1997. D1, D2, and D3 Feasibility Evaluations for SWMU 91 were submitted to regulators during 1997. The D2 Proposed Remedial Action Plan and D0 ROD issued in December recommend the use of the Lasagna process for full-scale remediation of the SWMU 91 site.

WAG 22 (SWMU 2)

SWMU 2 includes the C-749 burial area. A path forward meeting with the regulatory agencies was conducted for SWMU 2 in April of 1997. The D0 and D1 Data Summary Reports were issued in 1997 with a Comment Response Summary Table completed in July of 1997. Regulatory agencies have agreed that a D2 version will not be required and that the Comment Response Summary Table is all that is necessary. The SWMU 2 D0 Feasibility Study was completed in August of 1997.

Temporary piezometers installed in the UCFS during the SWMU 2 remedial investigation were abandoned during 1997. The purpose of these piezometers was to determine direction of a lateral gradient with the UCFS. The piezometer measurements documented the presence of a shallow water table, near the top of the burial cells with a lateral hydraulic gradient sloping to the west.

WAG 22 (SWMU 7 & 30)

SWMUs 7 & 30 are located adjacent to one another in the northwest corner of the PGDP security area. The D0 and D1 Remedial Investigation Reports for SWMUs 7 & 30 were completed during May and July of 1997 respectively. The D0 Feasibility Study was completed in September of 1997.

Temporary piezometers installed in the UCFS during the SWMU 7 & 30 remedial investigation were abandoned during 1997. The purpose of these piezometers were to determine if water is perched within

the waste burial grounds. The piezometer measurements documented the presence of an area-wide shallow water table, near the top of the burial cells.

Applicable Monitoring Standards

Table 9.1 lists the analysis parameters and regulatory limits or guidelines for groundwater monitoring wells. This table also shows regularly sampled wells that met or exceeded the reference value at least once during 1997.

Groundwater Monitoring Results

Groundwater monitoring results from all sampling efforts conducted by the Paducah Site are compiled in the Environmental Information Management System (EIMS) data base. A complete listing of analytical results are available upon request from the Bechtel Jacobs Company LLC Public Affairs Department.

Table 9.1 Applicable groundwater monitoring 1997 results at Paducah Site

Parameter	Applicable Value	Reference	Wells exceeding reference value at least once in 1997
Aluminum	0.05-0.2 mg/L	a	MW100, MW237, MW 238, MW240, MW241, MW242, MW245, MW246, MW249, MW250, MW300-303
Antimony	0.006 mg/L	b	None
Arsenic	0.05 mg/L	b	None
Barium	1.0 mg/L	b	None
Beryllium	0.004 mg/L	b	None
Cadmium	0.005 mg/L	b	None
Chloride	250 mg/L	a	None
Chromium	0.1 mg/L	b	MW124, MW126, MW145, MW181, MW220, MW221, MW222, MW223, MW226, MW242, MW243, MW255, MW263, MW265 -267, MW270-277, MW284, MW291-294
Color (of Water)	15 Units	a	None
Copper	1.3 mg/L	a	None
Fluoride	4.0 mg/L	b	None

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Parameter	Applicable Value	Reference	Wells exceeding reference value at least once in 1997
Iron	0.30 mg/L	a	MW100, MW102, MW120-122, MW124, MW126, MW140, MW142, MW145, MW150, MW179, MW181, MW194, MW199, MW220-224, MW233 -250, MW255, MW263-277, MW284, MW291-294, MW300-303,
Lead	0.05 mg/L	b	None
Manganese	0.05 mg/L	a	MW100, MW102, MW120-122, MW140, MW150, MW196, MW199, MW233, MW234, MW236, MW238, MW239, MW240, MW241, MW242, MW245-249, MW255, MW294, MW300-303
Mercury	0.002 mg/L	b	None
Nickel	0.1 mg/L	b	MW181, MW220-223, MW243, MW265-267, MW270- 277, MW292, MW293, MW294, MW300
Nitrate as nitrogen	10 mg/L	b	None
pH	6.5-8.5 SU ^b	a	MW121
Selenium	0.01 mg/L	b	None
Silver	0.05 mg/L	b	None
Sulfate	250 mg/L	a	None
Thallium	0.002 mg/L	b	None
Total dissolved solids	500 mg/L	a	None
Water turbidity	6.6 NTU ^c	b	MW124, MW126, MW159, MW179, MW181, MW220-224, MW233, MW234-250, MW255, MW263, MW265-277, MW284, MW291-294
Zinc	5.0 mg/L	a	MW222
Benzene	0.005 mg/L	b	R82
Carbon tetrachloride	0.005 mg/L	b	None
1,2-Dichloroethane	0.005 mg/L	b	R82
cis-1,2-Dichloroethene	0.07 mg/L	b	MW157, MW186, MW187, MW300

Parameter	Applicable Value	Reference	Wells exceeding reference value at least once in 1997
trans-1,2-Dichloroethene	0.1 mg/L	b	None
1,1-Dichloroethene	0.007 mg/L	b	MW300
Ethylbenzene	0.7 mg/L	b	MW96
Polychlorinated biphenyls	0.0005 mg/L	b	None
Tetrachloroethene	0.005 mg/L	b	MW66
Toluene	1 mg/L	b	None
1,1,2-Trichloroethane	0.005 mg/L	b	None
Trichloroethene	0.005 mg/L	b	MW20, MW64, MW65, MW66, MW85, MW88, MW91, MW94, MW108, MW124, MW126, MW134, MW145, MW155, MW157, MW159, MW168, MW178, MW185-188, MW193, MW197, MW201-203, MW221, MW224, MW226, MW227, MW233-236, MW238-245, MW247-250, MW255, MW256, MW258, MW260-263, MW276, MW277, MW283, MW284, MW288, MW291-294, MW300, MW333, MW337, MW340, R2, R5, R424, R432
Vinyl chloride	0.002 mg/L	b	MW186
Xylene	10 mg/L	b	None
Neptunium-237	1.2 pCi/L	c	None
Plutonium-239	1.2 pCi/L	c	None
Radon-222	300 pCi/L	d	MW100, MW103, MW142, MW150, MW194, MW199, MW196, MW233-236, MW238, MW239, MW240, MW241, MW245, MW246, MW248, MW249
Radium-226	5.0 pCi/L	b	None
Technetium-99	3790 pCi/L	d	MW262
Thorium-230	12 pCi/L	c	None
Uranium	0.02 mg/L	d	MW135, MW182, MW303
Gross alpha	15 pCi/L	b	MW182, MW248, MW261, MW262, MW301, MW303, R2

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Parameter	Applicable Value	Reference	Wells exceeding reference value at least once in 1997
Gross beta	50 pCi/L	b	MW66, MW121, MW135, MW152, MW155, MW166, MW168, MW178, MW181, MW 182, MW185, MW186, MW 197, MW200, MW201, MW233-236, MW238, MW240-243, MW247-250, MW261, MW262, MW268, MW269, MW271-275, MW301, MW303, MW328, MW340, R2, R302

- a. 40 CFR Pt. 143. Safe Drinking Water Act-National Secondary Drinking Water Regulations, as amended.
- b. 40 CFR Pt. 141. Safe Drinking Water Act-National Primary Drinking Water Regulations, as amended.
- c. Four percent of derived concentration guidelines for air and water (4 mrem/year), DOE Order 5400.5, Radiation Protection of the Public and the Environment.
- d. Proposed maximum contaminant level in 56 Federal Register, July 18, 1991, National Primary Drinking Water Regulations for Radionuclides in Drinking Water. (Previous standard for ^{99}Tc was 900 pCi/L.)

10. Quality Assurance

Abstract

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

Introduction

The Paducah Site maintains a quality assurance/quality control (QA/QC) program to verify the integrity of data generated within the environmental monitoring program. Each aspect of the monitoring program, from sample collection to data reporting, must address QA, QC, and quality assessment standards. Requirements and guidelines for the QA/QC program at the Paducah Site are established by Department of Energy (DOE) Order 5700.6C, *Quality Assurance*; state and federal regulations; and documentation from the Environmental Protection Agency (EPA), the American National Standards Institute, the American Society of Mechanical Engineers, and the American Society for Quality Control. The QA/QC program specifies organizational, inspective, and programmatic elements to control equipment, design, documents, nonconformances, and records. Emphasis is placed on planning, audits, records, and corrective actions.

Through a work authorization form, United States Enrichment Corporation (USEC) through Lockheed Martin Utility Services (Utility Services) supplies DOE with the personnel to support environmental sampling activities and the quality requirements for monitoring programs. The *LMES PGDP Groundwater Program Quality Assurance Plan*, (Blewett, 1997) provides a description of the quality elements regarding groundwater. This document defines the relationship of each element of the environmental monitoring program to key QA/QC requirements. Training requirements, sample custody, procedures, instrument calibration, and maintenance are a few of the subjects discussed in each document. The Energy Systems Quality Services Organization and the Utility Services Environmental Management Group perform a variety of functions critical to the environmental monitoring program. Included in the responsibilities of these groups are developing data quality objectives, conducting surveillances, reporting problems, verifying, validating, and assessing data. Other roles include preparing procedures and writing and reviewing QA plans.

Field Sampling and Monitoring

Basic Concepts and Practices

From the point of conception of any sampling program, QA/QC plays an important role. Each monitoring or sampling organization plans a project, sets objectives, identifies responsibilities, and selects sampling methods and the appropriate sampling instruments or devices according to use and cleaning practices recommended by the American Society for Testing and Materials, the EPA, or other established authorities. The number of samples, location of sampling sites, sampling methods, sampling schedules,

and coordination of sampling and analytical resources to meet critical completion times must be decided. The rationale for these and other decisions is mainly the responsibility of the sampling organization, which receives input from compliance and analytical organizations. Sampling plans and field documentation are prepared as needed.

Chain-of-custody documentation is maintained from the point of sampling, and samples are properly protected until they are placed in the custody of analytical laboratory control programs. In the laboratory, chain-of-custody procedures are followed until a sample is analyzed. For hazardous waste samples, chain-of-custody procedures are maintained to the point of sample disposal. The performance of field analytical procedures is documented using EPA-approved methods when available.

The quality control program for both groundwater and environmental monitoring activities specifies a target rate of 5% on field samples. Table 10.1 shows the types of QA/QC samples used and what areas are controlled. Monitoring QA/QC samples are chosen so that the combination of samples meets the targeted QA/QC rate. The sample combination varies with the activity performed.

Table 10.1 Types of QA/QC samples and controlled areas

Monitoring QA/QC	Laboratory QA/QC	Monitoring/lab QA performed by the laboratory
Duplicate	Replicates	Control samples
Trip blanks	Reagent blanks	Performance evaluations
Equipment blanks	Matrix spikes	
Equipment rinsates	Matrix spike duplicates	

Analytical Quality Assurance

The analytical laboratories at the Paducah Site continue a long tradition of QA. Such terms as sound methodology, safe practices, analytical recovery, and QC are well defined. Also well established is the use of statistical methods to establish precision, accuracy, lowest concentration reported, and minimum detection level. Since the beginning of operations at the site, the analytical laboratories have been involved in the handling and analysis of materials of high purity and hazardous materials, for which strict accountability is required. QA is, therefore, a daily responsibility.

After receiving samples from the sampling group or the sample transporter, the laboratory custodian assumes responsibility for proper protection and handling of the samples. Using guidance from the EPA, the laboratories document the steps in handling, analysis, and approval of results. The performance of all analytical procedures is documented using EPA-approved methods when they are available.

A key feature in analytical QA is QC. The Paducah Site participates in programs that are internal to the laboratory (i.e., internal controls), and external to the plant (i.e., independent controls).

Internal Quality Control

All analytical activities are supported by the use of standard, or reference, materials. The compositions of these materials are well known and are used in the calibration of instruments, method standardization,

spike additions for recovery testing, and other practices. Certified standards from the National Institute of Standards and Technology, the EPA, or other DOE laboratories are often used in such work.

These internal programs are the mainstay of analytical QC and the basis for ensuring reliable results on a daily basis and between batches. The total effort in these programs is at least 10% of the total laboratory effort (according to EPA expectations) and approaches 20% for some activities.

Internal QA and QC programs have become major factors in environmental analysis procedures because of the low levels of pollutants measured and the relationships of these measured values to regulatory limits. These QC programs also provide for laboratory analyst training and qualification in the many procedures used. Daily QC data are stored in a retrievable manner so that they can be related to the analytical results they support.

Independent Quality Control

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

Data Management

The data generated by the EM and ER programs are stored in the Environmental Information Management System (EIMS), a consolidated site data system for tracking, management, verification, validation, and reporting of environmental data. The EIMS uses a variety of references and code lists to ensure consistency and to standardize the presentation of data for users.

EIMS performs a computer-based verification of the field and analytical data that are entered from field logbooks and forms or analytical data packages. The verification procedures check for inconsistencies with the reference and codes tables. Examples of these checks include valid sample type, spelling of the analysis name, units, and appropriate methods. Data that pass all of the initial verification checks are compared with standardized criteria, which are established by the data generator during the development of the data quality objectives. Examples of these checks include holding time exceedences, comparison with historical statistics, and comparison with regulatory or permit limits. Electronic verification flags are attached to the data as a result of this step. These flags are available to persons using the data to aid in assessing how usable the data are.

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REFERENCES

American Nuclear Society (ANS). 1986. *Glossary of Terms in Nuclear Science and Technology*, American Nuclear Society.

BEIR. 1990. *Health Effects of Exposure to Low Levels of Ionizing Radiation*, Committee on the Biological Effects of Ionizing Radiation (BEIR V), National Research Council, National Academy of Sciences, National Academy Press, Washington, D.C.

Blewett, Jennifer R. 1997. *LMES PGDP Groundwater Program Quality Assurance Plan*, Lockheed Martin Energy Systems, Inc., Paducah Gaseous Diffusion Plant

CH2M Hill. 1990. *Draft Results of the Site Investigation Phase I at the Paducah Gaseous Diffusion Plant, Paducah, Ky.*, KY/ER-4, Paducah Gaseous Diffusion Plant, Paducah, Ky.

CH2M Hill. 1991a. *Results of the Public Health and Ecological Assessment, Phase II at the Paducah Gaseous Diffusion Plant (Draft)*, KY/SUB/13B-97777C P-03/1991/1.

CH2M Hill. 1991b. *Results of the Site Investigation, Phase I, at the Paducah Gaseous Diffusion Plant, Paducah, Ky.*, KY/ER-4, Paducah Gaseous Diffusion Plant, Paducah, Ky.

CH2M Hill. 1992a. *Results of the Site Investigation, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/SUB/13B-97777C P-03/1991/1, Paducah Gaseous Diffusion Plant, Paducah, Ky.

CH2M Hill. 1992b. *Results of the Public Health and Ecological Assessment, Phase II, at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, KY/SUB/13B-97777C P-03/1991/1, Paducah Gaseous Diffusion Plant, Paducah, Ky.

Clausen, J. L. 1996. *Paducah Gaseous Diffusion Plant Groundwater Protection Program Plan Addendum to Sampling and Analysis Plan*, KY/ER-2/Addendum 4, Rev. 2, Lockheed Martin Energy Systems, Inc., Paducah Gaseous Diffusion Plant.

International Commission on Radiological Protection (ICRP). 1979. *Annals of ICRP Publication 30, Parts I and II, Limits of Intakes of Radionuclides by Workers*, ICRP Publication 30, Pergamon, Oxford, N.Y.

Jacobs EM Team. 1997. Numerical Ground-Water Recalibration and Evaluation of the Northwest Plume Interim Remedial Action Report for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky.

Jinks, S. M., and M. Eisenbud. 1972. "Concentration Factors in Aquatic Environment," *Radia. Data Rep.* 13, 243.

Paducah Site

Kszos, L. A. (ed). 1998. *Report on the Biological Monitoring Program at Paducah Gaseous Diffusion Plant January December 1997*, ORNL/TM-13592, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Kumazawa S., et al. 1984. *Occupational Exposure to Ionizing Radiation in the United States: A Comprehensive Review for the Year 1980 and a Summary of Trends for the Years 1960-1985*, EPA/520/1-8-005, U.S. Government Printing Office, Washington, D.C.

Lockheed Martin Energy Systems, Inc. (LMES). 1995. *Environmental Monitoring Plan*, KY/EM-117, Lockheed Martin Energy Systems, Inc., Paducah Site.

McGraw-Hill. 1989. *McGraw-Hill Dictionary of Scientific and Technical Terms*, 4th ed. McGraw-Hill, Inc.

McMurry, S., and P. Smith. 1997. *Polychlorinated Biphenyl and Metal Exposure of Small Mammals at the Paducah Gaseous Diffusion Plant, McCracken County, Kentucky*, Clemson University, Pendleton, South Carolina.

Miller, G. R., 1997. *Paducah Gaseous Diffusion Plant Groundwater Protection Program Management Plan*, Lockheed Martin Energy Systems, Inc., Paducah Gaseous Diffusion Plant.

National Council on Radiation Protection and Measurements (NCRP). 1987. "Ionizing Radiation Exposure of the Population of the United States," *NCRP Report No. 93*, Washington, D.C.

National Council on Radiation Protection and Measurements (NCRP). 1989. "Exposure of the U.S. Population from Diagnostic Medical Radiation," *NCRP Report No. 100*, Bethesda Md.

Phipps, T. L., and L. A. Kszos. 1997. *Bioavailability Study for the Paducah Gaseous Diffusion Plant*, ORNL/TM-13258, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Science Applications International Corporation (SAIC). 1991a. *Summary of Alternatives for Remediation of Off-Site Contamination at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (Draft).

Science Applications International Corporation (SAIC). 1992. *Draft Environmental Assessment: Construction and Operation of Residential Landfill Cell No. 3 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (Rev. 2), Oak Ridge, Tenn.

U. S. Department of Energy (DOE). January 1991. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0173T, Washington, D.C.

U.S. Department of Energy (DOE). July 1988. *Internal Dose Conversion Factors for Calculations of Dose to the Public*, DOE/EH-00071, U.S. Department of Energy.

U. S. Environmental Protection Agency (EPA). July 1989. *Exposure Factors Handbook*, EPA 600/8-89-043, U. S. Environmental Protection Agency.

Westinghouse Savannah River Company. 1991. *Savannah River Site Environmental Report for 1993, Summary Pamlet*, WSRC-TR-94-076.

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Glossary

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

activity - See radioactivity.

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.

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.

analyte - A constituent or parameter being analyzed.

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

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

assimilate - To take up or absorb.

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

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

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

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

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

Ci-See curie.

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 water's capacity to convey an electric current. 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.

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

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

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

kilocurie (kCi) - 10^3 Ci, one thousand curies; 3.7×10^{13} disintegrations per second.

millicurie (mCi) - 10^{-3} Ci, one-thousandth of a curie; 3.7×10^7 disintegrations per second.

microcurie (gCi) - 10^{-6} Ci, one-millionth of a curie; 3.7×10^4 disintegrations per second.

picocurie (pCi) - 10^{-12} Ci, one-trillionth of a curie; 0.037 disintegrations per second.

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

DCG - See derived concentration guide.

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.

decontamination and decommissioning - See Environmental Restoration.

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

derived concentration guide (DCG) - The concentration of a radionuclide in air or water that under conditions of continuous exposure for one year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation) would result in either an effective dose equivalent of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and the lens of the eye. The guidelines for radionuclides in air and water are given in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*.

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

DNAPL - See dense nonaqueous phase liquid.

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.

dosimeter - A portable detection device for measuring the total accumulated exposure to ionizing radiation.

dosimetry - The theory and application of principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with using various types of radiation instruments to make measurements.

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 U.S. Environmental Protection Agency.

DWS - See drinking water standards.

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

effluent monitoring - The collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying the release of contaminants, assessing radiation exposures to members of the public, and demonstrating compliance with applicable standards.

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

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

external radiation - Exposure to ionizing radiation when the radiation source is located outside the body.

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

flora - The population of plants at 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.

gamma spectrometry - A system consisting of a detector, associated electronics, and a multichannel analyzer that is used to analyze samples for gamma-emitting radionuclides.

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

Geiger-Mueller (GM) counter - A highly sensitive, gas-filled radiation detector that operates at voltages sufficiently high to produce ionization. The counter is used primarily in the detection of gamma radiation and beta emission. It is named for Hans Geiger and W. Mueller, who invented it in 1928.

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

groundwater, unconfined - Groundwater exposed to the unsaturated zone.

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

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

hydrogeology - Hydraulic aspects of site geology.

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

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

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

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

irradiation - Exposure to radiation.

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

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

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

LLD - See lower limit of detection.

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

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

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

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

minimum detectable concentration - The smallest amount or concentration of a radionuclide that can be distinguished in a sample by a given measurement system at a preselected counting time and at a given confidence level.

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

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

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

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

outcrop - A place where groundwater is discharged to the surface. Springs, swamps, and beds of streams and rivers are the outcrops of the water table.

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 g/L or ng/mL.

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

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

pH - A measure of the hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH from 0 to 6, neutral solutions have a pH equal to 7, and basic solutions have a pH greater than 7.

piezometer - An instrument used to measure the potentiometric surface of the groundwater; also, a well designed for this purpose.

ppb - See part per billion.

ppm - See part per million.

process water - Water used within a system process.

process sewer - Pipe or drain, generally located underground, used to carry off process water or waste matter.

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

QA - See quality assurance.

QC - See quality control.

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

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

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

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

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

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

radioisotopes - Radioactive isotopes.

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

RCRA - See Resource Conservation and Recovery Act.

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 x 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 2.58×10^4 coulombs per kilogram of air.

routine radioactive release - A planned or scheduled release of radioactivity to the environment.

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

sidegradient well - A well that intercepts groundwater flowing next to a site; a sidegradient well is located neither upgradient nor downgradient to the monitored site.

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.

solid waste disposal facility (SWDF) - A place for burying unwanted radioactive material to prevent escape of radioactivity. The surrounding water acts as a shield. Such material is placed in watertight, noncorroding containers so that it cannot leach out and invade underground 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.

Sv - See sievert.

SWDF - See solid waste disposal facility.

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.

TLD - See thermoluminescent dosimeter.

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.

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 compounds - 1, 1, 1 -TCA, perclene, and triclene are common names for trichloroethane, tetrachloroethylene, and trichloroethylene, respectively. Used in many processes, the levels of these carcinogenic compounds must be kept to a minimum. They are measured by volatile organic analyses content.

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

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

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

Appendix A: Radiation

This appendix gives basic facts about radiation. This information is intended as a basis for understanding the dose associated with releases from the Paducah Site, not as a comprehensive discussion of radiation and its effects on the environment and biological systems. The McGraw-Hill dictionary defines radiation and radioactivity as follows:

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

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

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

ATOMS AND ISOTOPES

All matter is made up of atoms. An atom is "a unit of matter consisting of a single nucleus surrounded by a number of electrons equal to the number of protons in the nucleus" (ANS 1986). The number of protons in the nucleus determines an element's atomic number, or chemical identity. With the exception of hydrogen, the nucleus of each type of atom also contains at least one neutron. Unlike protons, the number of neutrons may vary among atoms of the same element. The number of neutrons and protons determines the atomic weight. Atoms of the same element with a different number of neutrons are called isotopes. In other words, isotopes have the same chemical properties but different atomic weights. Figure A.1 depicts isotopes of the element hydrogen. Another example is the element uranium, which has 92 protons; all isotopes of uranium, therefore, have 92 protons. However, each uranium isotope has a different number of neutrons. Uranium-234 has 92 protons and 142 neutrons; ^{235}U has 92 protons and 143 neutrons; ^{238}U has 92 protons and 146 neutrons.

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

RADIATION

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

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

Ionizing Radiation

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

Nonionizing Radiation

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

SOURCES OF RADIATION

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

Background Radiation

Many materials are naturally radioactive. In fact, this naturally occurring radiation is the major source of radiation in the environment. Though people have little control over the amount of background radiation to which they are exposed, this exposure must be put into perspective. Background radiation remains

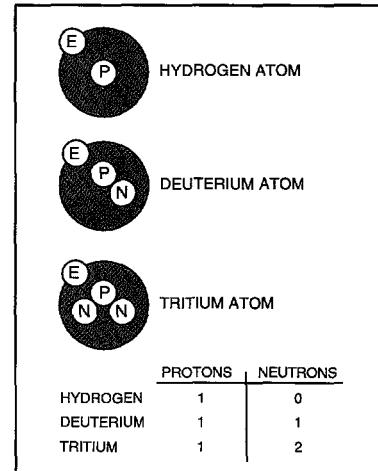


Figure A.1 Isotopes of the element hydrogen.

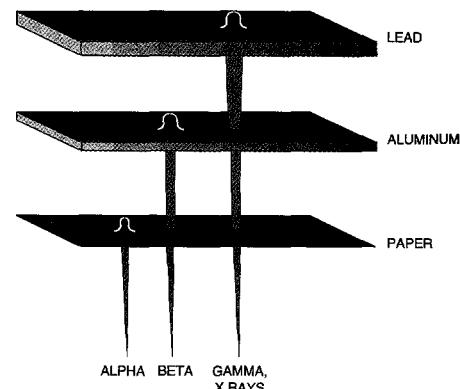


Fig. A.2. Penetrating power of radiation. Some types of radiation can be easily shielded against. For example, a sheet of paper is sufficient to stop an alpha particle. Gamma rays can pass through paper but can be stopped by the appropriate amount of lead. Radiation's ability to penetrate is an important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

relatively constant over time; background radiation present in the environment today is much the same as it was hundreds of years ago.

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

Cosmic Radiation

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

Terrestrial Radiation

Terrestrial radiation refers to radiation emitted from radioactive materials in the earth's rocks, soils, and minerals. Radon (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

Radioactive material in the environment enters the body through the air people breathe and the food they eat; it also can enter through an open wound. Natural radionuclides in the body include isotopes of uranium, thorium, radium, radon, polonium, bismuth, and lead in the ^{238}U and ^{212}Th decay series. In addition, the body contains isotopes of potassium (^{40}K), rubidium (^{87}Rb), and carbon (^{14}C).

Human-Made Radiation

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

Consumer Products

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

Medical Sources

Radiation is an important tool of diagnostic medicine and treatment and, in this use, is the main source of exposure to human-made radiation. Exposure is deliberate and directly beneficial to the patients exposed.

Generally, diagnostic or therapeutic medical exposures result from X ray beams directed to specific areas of the body. Thus, all body organs generally are not irradiated uniformly. Radiation and radioactive materials are also used in a wide variety of pharmaceuticals and in the preparation of medical instruments, including the sterilization of heat-sensitive products such as plastic heart valves. Nuclear medicine examinations and treatment involve the internal administration of radioactive compounds, or radiopharmaceuticals, by injection, inhalation, consumption, or insertion. Even then, radionuclides are not distributed uniformly throughout the body.

Other Sources

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

PATHWAYS OF RADIATION

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

MEASURING RADIATION

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

Activity

When measuring the amount of radiation in the environment, what is actually being measured is the rate of radioactive decay, or activity. The rate of decay varies widely among the various radioisotopes. For that reason, 1 g of a radioactive substance may contain the same amount of activity as several tons of another material. This activity is expressed in a unit of measure known as a curie (Ci). More specifically, 1 Ci = 3.7E+10 (37,000,000,000) atom disintegrations per second (dps). In the international system of units, 1 dps = 1 becquerel (Bq).

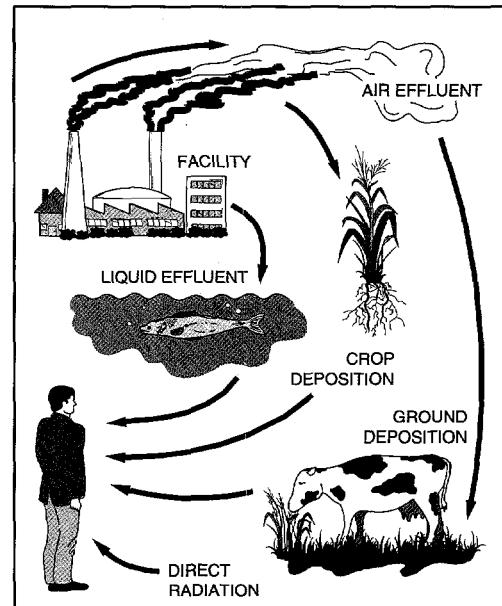


Figure A.3 Possible radiation pathways.

Absorbed Dose

The total amount of energy absorbed per unit mass as a result of exposure to radiation is expressed in a unit of measure known as a rad. In the international system of units, 100 rad = 1 gray (Gy). However, in terms of human health, it is the effect of the absorbed energy that is important because some forms of radiation are more harmful than others as a result of their energy deposition pattern.

Dose Equivalent

The measure of potential biological damage caused by exposure to and subsequent absorption of radiation is expressed in a unit of measure known as a rem. One rem of any type of radiation has the same total damaging effect. Because a rem represents a fairly large dose, dose is expressed as a millirem (mrem), or 1/1000 of a rem. In the international system of units, 100 rem = 1 Sievert (Sv); 100 mrem = 1 millisievert (mSv).

DOSE

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

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

Comparison of Dose Levels

A scale of dose levels is presented in Table A.1. Included is an example of the type of exposure that may cause such a dose or the special significance of such a dose. This information is intended to help the reader become familiar with the type of doses individuals may receive.

Dose from Cosmic Radiation

The average annual dose received by residents of the United States from cosmic radiation is about 27 mrem (0.27 mSv) (NCRP 1987). The average annual dose from cosmic radiation received by residents in the Paducah area is about 45 mrem (0.45 mSv).

Paducah Site**Table A.1 Comparison and description of various dose levels**

Dose level	Description
1 mrem (0.01 mSv)	Approximate daily dose from natural background radiation, including radon
2.5 mrem (0.025 mSv)	Cosmic dose to a person on a one-way airplane flight from New York to Los Angeles
10 mrem (0.10 mSv)	Annual exposure limit, set by the EPA for exposures from airborne emissions from operations of nuclear fuel cycle facilities, including power plants and uranium mines and mills
45 mrem (0.45 mSv)	Average yearly dose from cosmic radiation received by people in the Paducah area
46 mrem (0.46 mSv)	Estimate of the largest dose any off-site person could have received from the March 28, 1979, Three Mile Island nuclear power plant accident
66 mrem (0.66 mSv)	Average yearly dose to people in the United States from human-made sources
100 mrem (1.00 mSv)	Annual limit of dose from all U.S. Department of Energy facilities to a member of the public who is not a radiation worker
110 mrem (1.10 mSv)	Average occupational dose received by U.S. commercial radiation workers in 1980
244 mrem (2.44 mSv)	Average dose from an upper gastrointestinal diagnostic X-ray series
300 mrem (3.00 mSv)	Average yearly dose to people in the United States from all sources of natural background radiation
1-5 rem (0.01-0.05 Sv)	EPA protective action guidelines state that public officials should take emergency action when the dose to a member of the public from a nuclear accident will likely reach this range
5 rem (0.05 Sv)	Annual limit for occupational exposure of radiation workers set by the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy
10 rem (0.10 Sv)	The BEIR V report estimated that an acute dose at this level would result in a lifetime excess risk of death from cancer, caused by the radiation, of 0.8% (BEIR 1990)
25 rem (0.25 Sv)	EPA guideline for voluntary maximum dose to emergency workers for non-lifesaving work during an emergency
75 rem (0.75 Sv)	EPA guideline for maximum dose to emergency workers volunteering for lifesaving work
50-600 rem (0.50-6.00 Sv)	Doses in this range received over a short period of time will produce radiation sickness in varying degrees. At the lower end of this range, people are expected to recover completely, given proper medical attention. At the top of this range, most people would die within 60 days

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

Dose Terminology

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

Dose from Terrestrial Radiation

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

Dose from Internal Radiation

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

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

Dose from Consumer Products

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

Dose from Medical Sources

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

Dose from Other Sources

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

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

Appendix B: Radionuclide and Chemical Nomenclature

Nomenclature and half-life for radionuclides

Radionuclide	Symbol	Half-life	Radionuclide	Symbol	Half-life
Bismuth-210	^{210}Bi	5.01 days	Radium-226	^{226}Ra	1,602 years
Bismuth-214	^{214}Bi	19.7 minutes	Radon-222	^{222}Ra	3.821 days
Lead-206	^{206}Pb	Stable	Technetium-99	^{99}Tc	212,000 years
Lead-210	^{210}Pb	21 years	Thorium-230	^{230}Th	80,000 years
Lead-214	^{210}Pb	26.8 minutes	Thorium-231	^{231}Th	25.5 hours
Polonium-210	^{210}Po	138.9 days	Thorium-234	^{234}Th	24.1 days
Polonium-214	^{214}Po	164 microseconds	Uranium-234	^{234}U	247,000 years
Polonium-218	^{218}Po	3.05 minutes	Uranium-235	^{235}U	710,000,000 years
Potassium-40	^{40}K	1,260,000,000 years	Uranium-236	^{236}U	23,900,000 years
Protactinium-234m	$^{234\text{m}}\text{Pa}$	1. 17 minutes	Uranium-238	^{238}U	4,510,000,000 years

Nomenclature for elements and chemical constituents

Constituent	Symbol	Constituent	Symbol
Aluminum	Al	Manganese	Mn
Ammonia	NH ₃	Mercury	Hg
Antimony	Sb	Nickel	Ni
Arsenic	As	Nitrogen	N
Barium	Ba	Nitrate	NO ₃
Beryllium	Be	Nitrite	NO ₂
Cadmium	Cd	Oxygen	O
Calcium	Ca	Ozone	O ₃
Calcium carbonate	CaCO ₃	Phosphorus	P
Carbon	C	Phosphate	PO ₄
Chlorine	Cl	Potassium	K
Chromium	Cr	Radium	Ra
Chromium, hexavalent	Cr ⁶⁺	Radon	Rn
Cobalt	Co	Selenium	Se
Copper	Cu	Silver	Ag
Fluorine	F	Sodium	Na
Hydrogen fluoride	HF	Sulfate	SO ₄
Iron	Fe	Sulfur dioxide	SO ₂
Lead	Pb	Thorium	Th
Lithium	Li	Uranium	U
Magnesium	Mg	Zinc	Zn

Appendix C: Data

1. Radiological Effluent Monitoring

Table 1.1 1997 Annual Radiological Data Summary for Outfall K001

Analysis	Units	Minimum	Maximum	Average	Count	Rad Error
% U-235	Wt%	0.37	0.58	0.45	20	
Neptunium-237	pCi/L	-0.3	0.4	0.025	4	0.2
Plutonium-239	pCi/L	-0.03	0.01	-0.01	4	0.08
Dissolved Alpha	pCi/ml	-1	19	9.48	4	5.7
Dissolved Beta	pCi/ml	23	58	40.5	4	7
Suspended Alpha	pCi/L	-3.1	0.3	-1.3	4	-0.2
Suspended Beta	pCi/L	-1	8	3.5	4	1
Technetium-99	pCi/L	0	34	12.06	51	14
Thorium-230	pCi/L	-0.11	0.17	-0.01	4	0.52
Uranium	mg/L	0.001	0.072	0.016	94	

Table 1.2 1997 Annual Radiological Data Summary for Outfall K015

Analysis	Units	Minimum	Maximum	Average	Count	Rad Error
% U-235	Wt%	0.25	0.41	0.3	10	
Neptunium-237	pCi/L	-0.2	0.7	0.3	4	0.3
Plutonium-239	pCi/L	-0.02	0.05	0.02	4	0.09
Dissolved Alpha	pCi/ml	10.5	97.8	52.88	4	13.2
Dissolved Beta	pCi/ml	32	117	58.5	4	11
Suspended Alpha	pCi/L	0.8	5.9	2.2	4	2.2
Suspended Beta	pCi/L	6	18	13.5	4	3
Technetium-99	pCi/L	6	53	20.43	11	14
Thorium-230	pCi/L	-0.22	0.44	0.098	4	0.52
Uranium	mg/L	0.012	0.57	0.176	11	

Table 1.3 1997 Annual Radiological Data Summary for Outfall K017

Analysis	Units	Minimum	Maximum	Average	Count	Rad Error
% U-235	Wt%	NA*	NA*	NA*		
Neptunium-237	pCi/L	-0.3	0.1	-0.05	4	0.1
Plutonium-239	pCi/L	-0.09	0	-0.03	4	0.08
Dissolved Alpha	pCi/ml	-4.6	3.7	-0.48	4	1.6
Dissolved Beta	pCi/ml	5	26	12.5	4	4
Suspended Alpha	pCi/L	-3.6	-0.8	-1.7	4	-0.4
Suspended Beta	pCi/L	-7	1	-1.5	4	0
Technetium-99	pCi/L	0	2.2	1.05	4	11
Thorium-230	pCi/L	-0.05	0.02	-0.02	4	0.52
Uranium	mg/L	0.001	0.009	0.005	4	0

* %U-235 was not analyzed because uranium concentration was too low.

Table 1.4 1997 Annual Radiological Data Summary for Outfall K018

Analysis	Units	Minimum	Maximum	Average	Count	Rad Error
% U-235	Wt%	0.372	0.587	0.514	6	
Neptunium-237	pCi/L	-0.2	0.4	0.1	4	0.2
Plutonium-239	pCi/L	-0.009	0.04	0.015	4	0.09
Rad Alpha	pCi/ml	-0.5	8.9	4.525	4	3.2
Rad Beta	pCi/ml	-1	26	11.5	4	4
Suspended Alpha	pCi/L	-2	1.7	-0.05	4	0.7
Suspended Beta	pCi/L	-4	108	27.25	4	9
Technetium-99	pCi/L	0	57	23.81	10	14
Thorium-230	pCi/L	0.022	0.055	0.365	4	0.53
Uranium	mg/L	0.002	0.047	0.018	10	

2. Radiological Environmental Surveillance

Table 2.1 1997 Annual Radiological Data Summary for Sampling Station SW 1
Upstream Big Bayou Creek, Background

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Suspended Alpha	pCi/L	-2.8	2.8	-0.186	14	1.2
Suspended Beta	pCi/L	-2	6	1.4286	14	1
Dissolved Alpha	pCi/L	-5.6	2.2	-0.4	14	0.9
Dissolved Beta	pCi/L	0	10	4	14	2
Gross Gamma	pCi/ml	453.2	126.2	290	2	
Neptunium-237	pCi/L	-0.2	0.4	0.1571	28	0.2
Plutonium-239	pCi/L	-0.01	0.01	-0.004	28	0.08
Technetium-99	pCi/L	-1	9	4.1429	28	11
Thorium-230	pCi/L	-0.24	0.1	-0.031	28	0.49
Uranium	mg/L	ND	ND	ND	16	
Uranium-238	pCi/L	ND	ND	ND	16	

Table 2.2 1997 Annual Radiological Data Summary for Sampling Station SW 10
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Suspended Alpha	pCi/L	-3.7	1.7	-1.429	14	0.9
Suspended Beta	pCi/L	3	11	3.5714	14	2
Dissolved Alpha	pCi/L	-2.5	11.2	4.125	8	1.7
Dissolved Beta	pCi/L	4	19	9.75	8	3
Gross Gamma	pCi/ml	138.6	267.4	204.4	8	
Neptunium-237	pCi/L	-0.2	0.4	0.1286	28	0.3
Plutonium-239	pCi/L	-0.03	0	-0.019	28	0.08
Technetium-99	pCi/L	3	27	9.4286	28	12
Thorium-230	pCi/L	-0.14	0.05	-0.024	28	0.61
Uranium	mg/L	0.003	0.016	0.008	28	
Uranium-238	pCi/L	0	10.7	2.14	20	
% U-235	Wt%	0.247	0.288	0.2713	12	

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Table 2.3 1997 Annual Radiological Data Summary for Sampling Station SW 29
Upstream Ohio River

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Dissolved Alpha	pCi/L	-4.2	5.8	0.643	14	2.2
Dissolved Beta	pCi/L	-1	10	2.714	14	2
Suspended Alpha	pCi/L	-1.7	4	0.557	14	1.7
Suspended Beta	pCi/L	-4	6	2.286	14	1
Gross Gamma	pCi/L	149	251	200	4	
Neptunium-237	pCi/L	-0.1	0.5	0.157	28	0.3
Plutonium-239	pCi/L	-0.03	0.05	0.004	28	0.09
Technetium-99	pCi/L	0	7	3.429	28	11
Thorium-230	pCi/L	-53	0.18	-0.049	28	0.5
Uranium	mg/L	ND	ND	ND	28	
Uranium-238	pCi/L	ND	ND	ND	20	

Table 2.4 1997 Annual Radiological Data Summary for Sampling Station SW 5
Downstream Big Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Dissolved Alpha	pCi/L	-3.3	6.4	1.057	14	2.2
Dissolved Beta	pCi/L	2	44	16.143	14	6
Suspended Alpha	pCi/L	-1.8	1.7	-0.686	14	0.9
Suspended Beta	pCi/L	-3	4	1.429	14	1
Gross Gamma	pCi/ml	21.7	191.5	108.9	6	
Neptunium-237	pCi/L	-0.1	0.4	0.0857	28	0.3
Plutonium-239	pCi/L	-0.03	0.02	-0.01	28	0.08
Technetium-99	pCi/L	4	32	12.857	28	12
Thorium-230	pCi/L	-0.23	0.07	-0.051	28	0.49
Uranium	mg/L	0.002	0.009	0.0049	28	
Uranium-238	pCi/L	0	0	0	20	

Table 2.5 1997 Annual Radiological Data Summary for Sampling Station SW 64
Massac Creek, Background

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Dissolved Alpha	pCi/L	-4.3	0.1	-1.786	14	0
Dissolved Beta	pCi/L	-2	43	8	14	5
Suspended Alpha	pCi/L	-4	2.4	-0.986	14	1.1
Suspended Beta	pCi/L	-6	4	0	14	1
Gross Gamma	pCi/ml	0.0059	0.2978	0.1526	8	
Neptunium-237	pCi/L	-0.2	0.4	0.0714	28	0.3
Plutonium-239	pCi/L	-0.02	0.04	0	28	0.08
Technetium-99	pCi/L	-2	28	8.5714	28	12
Thorium-230	pCi/L	-0.08	0.12	-0.007	28	0.57
Uranium	mg/L	ND	ND	ND	28	
Uranium-238	pCi/L	ND	ND	ND	20	

Table 2.6 1997 Radiological Data Summary for Surface Water Location SW 8
Confluence of Big and Little Bayou Creeks

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Technetium-99	pCi/L	7	22	14.5	2	12

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Table 2.7 1997 Radiological Data Summary for Surface Water Location SW 11
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
% U-235	Wt%	0.516	0.516	0.516	4	
Gross Gamma	pCi/ml	0.269	0.269	0.269	2	
Neptunium-237	pCi/L	-0.2	0.4	0.143	28	0.2
Plutonium-239	pCi/L	-0.03	-0.004	-0.019	28	0.08
Suspended Alpha	pCi/L	-3.6	2.9	-0.243	14	1.3
Suspended Beta	pCi/L	-3	5	1.286	14	1
Technetium-99	pCi/L	0	19	7.714	28	12
Thorium-230	pCi/L	-0.35	0.07	-0.047	28	0.58
Uranium	mg/L	0.002	0.016	0.0063	28	
Uranium-238	pCi/L	0	0	0	16	
Dissolved Alpha	pCi/L	-60.9	4.3	-8.2	14	1.8
Dissolved Beta	pCi/L	3	1006	153.29	14	180

Table 2.8 1997 Radiological Data Summary for Surface Water Location SW 12
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Technetium-99	pCi/L	23	47	35.6	5	13

Table 2.9 1997 Radiological Data Summary for Surface Water Location SW 241
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Technetium-99	pCi/L	43	68	55.5	6	15

3. Dose

Table 3.1 Internal Dose Factors for an Adult

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

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

^b Includes allowance for skin absorption.

Paducah Site

4. Nonradiological Effluent Monitoring

Table 4.1 1997 Nonradiological Effluent Data Summary for Outfall 001

Analysis	Units	Minimum	Maximum	Average	Count
Hardness as CaCO ₃	mg/L CaCO ₃	56	377	263	48
Aluminum	mg/L	ND	0.79	0.55	22
Cadmium	mg/L	ND	ND	ND	23
Chlorine	mg/L	ND	ND	ND	50
Copper	mg/L	ND	ND	ND	22
Iron	mg/L	ND	0.67	0.35	22
Lead	mg/L	ND	0.01	0.002	20
Magnesium	mg/L	4.5	24.7	14.62	9
Nickel	mg/L	ND	ND	ND	22
Phosphorus	mg/L	0.11	0.46	0.21	51
Potassium	mg/L	ND	24.1	12.05	6
Sodium	mg/L	14.9	119	64.28	9
Zinc	mg/L	ND	ND	ND	11
TOX	ug/L	0.07	248	144.3	87
Flow	MGD	0.38	12.4	2.624	106
Oil & Grease	mg/L	ND	ND	ND	52
pH	SU	7.37	9.21	8.25	61
Specific Conductance	umho/cm	196	1440	974	95
Temperature	F	42	91	67.22	50
Total Suspended Solids	mg/L	4	38	18.25	48
PCB	ug/L	ND	ND	ND	13
Acetone	ug/L	ND	ND	ND	12
Isopropanol	ug/L	ND	ND	ND	11
Trichloroethene	ug/L	ND	ND	ND	12

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Table 4.2 1997 Nonradiological Effluent Data Summary for Outfall 015

Analysis	Units	Minimum	Maximum	Average	Count
Hardness as CaCO ₃	mg/L CaCO ₃	117	314	186	11
Aluminum	mg/L	ND	3.9	1.32	11
Cadmium	mg/L	ND	ND	ND	11
Chromium	mg/L	ND	ND	ND	11
Copper	mg/L	ND	ND	ND	11
Iron	mg/L	0.4	3.8	104	11
Lead	mg/L	ND	0.008	0.003	10
Nickel	mg/L	ND	ND	ND	11
Zinc	mg/L	ND	ND	ND	11
Flow	MGD	5	5.5	5.05	11
Oil & Grease	mg/L	ND	5.5	5.05	11
pH	SU	7.4	8.3	7.83	11
Temperature	F	78	78	78	1
Total Suspended Solids	mg/L	6	307	40.4	11
PCB	ug/L	ND	ND	ND	10
Trichloroethene	ug/L	ND	ND	ND	11

Table 4.3 1997 Nonradiological Effluent Data Summary for Outfall 017

Analysis	Units	Minimum	Maximum	Average	Count
Hardness as CaCO ₃	mg/L CaCO ₃	64	327	172	12
Aluminum	mg/L	ND	2.68	3.11	11
Cadmium	mg/L	ND	ND	ND	11
Chromium	mg/L	ND	ND	ND	11
Copper	mg/L	ND	0.015	0.012	11
Iron	mg/L	0.2	2.17	0.81	11
Lead	mg/L	ND	0.006	0.002	10
Nickel	mg/L	ND	ND	ND	11
Zinc	mg/L	ND	ND	ND	11
Flow	MGD	0.004	1.07	0.25	12
Oil & Grease	mg/L	ND	16.1	5.85	13
pH	SU	7.4	10.5	8.1	11
Temperature	F	80	80	80	1
Total Suspended Solids	mg/L	8	124	27.7	12
PCB	ug/L	ND	ND	ND	11
Trichloroethene	ug/L	ND	ND	ND	12

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Table 4.4 1997 Nonradiological Effluent Data Summary for Outfall 018

Analysis	Units	Minimum	Maximum	Average	Count
Hardness as CaCO ₃	mg/L CaCO ₃	55	141	101	10
Aluminum	mg/L	ND	5.83	2.57	9
Cadmium	mg/L	ND	ND	ND	10
Chromium	mg/L	ND	ND	ND	9
Copper	mg/L	ND	0.012	0.012	9
Iron	mg/L	0.58	5.63	2.56	9
Lead	mg/L	ND	0.004	0.002	8
Nickel	mg/L	ND	ND	ND	9
Zinc	mg/L	ND	ND	ND	9
Flow	MGD	0.004	5.46	0.63	11
Oil & Grease	mg/L	ND	ND	ND	10
pH	SU	7.2	8.1	7.58	10
Temperature	F	73	73	73	1
Total Suspended Solids	mg/L	10	46	31.2	10
PCB	ug/L	ND	ND	ND	10
Trichloroethene	ug/L	ND	ND	ND	10

Table 4.5 1997 Nonradiological Effluent Data Summary for Landfill Outfall UL001

Analysis	Units	Minimum	Maximum	Average	Count
Hardness as CaCO ₃	mg/L CaCO ₃	ND	ND	ND	2
Chlorine	mg/L	73	118	93.14	7
Flow	MGD	0.034	0.36	0.11	9
pH	SU	7.03	8.88	7.8	9
Specific Conductance	umho/cm	157	223	196	7
Temperature	F	46	46	46	2
Total Suspended Solids	mg/L	ND	25	16.2	6
Turbidity	NTU	15	15	15	1

Table 4.6 Compliance Experience under Interim KPDES Limits for 1997
Maximum daily limits for TCE at outfalls 017 and 018

Outfall	Frequency	TCE Limit ($\mu\text{g/L}$)
017	Monthly ^a	81
018	Monthly	81

^a Duplicate injection precision not met.

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5. Nonradiological Environmental Monitoring

Table 5.1 1997 Nonradiological Data Summary for Surface Water Location SW1
Upstream Big Bayou Creek, Background

Analysis	Units	Minimum	Maximum	Average	Count
Chloride	mg/L	8.3	18.2	13.87	20
Fluoride	mg/L	0.1	0.18	0.13	13
Hardness as CaCO ₃	mg/L CaCO ₃	55	71	62.17	14
Nitrate as Nitrogen	mg/L	1	1.2	1.04	13
Phosphate as P	mg/L	ND	ND	ND	13
Sulfate	mg/L	11.4	28.4	20.96	13
Hexavalent Chromium	mg/L	ND	ND	ND	13
Aluminum	mg/L	0.5	0.68	0.54	21
Cadmium	mg/L	ND	ND	ND	7
Chromium	mg/L	ND	ND	ND	7
Copper	mg/L	ND	ND	ND	7
Iron	mg/L	0.32	1.13	0.6	7
Lead	mg/L	0.001	0.002	0.002	6
Nickel	mg/L	ND	ND	ND	7
Phosphorus (P)	mg/L	0.05	0.07	0.05	7
Zinc	mg/L	ND	ND	ND	7
BOD	mg/L	5	10	5.71	7
Flow	MGD	0.07	3.37	0.65	41
pH	SU	6.45	9.76	7.74	57
Temperature	F	33	88	62.5	44
Total Suspended Solids	mg/L	4	15	10.43	7
PCB	ug/L	ND	ND	ND	7
Acetone	ug/L	ND	ND	ND	7
Isopropanol	ug/L	ND	ND	ND	7
Trichloroethene	ug/L	ND	ND	ND	7

Table 5.2 1997 Nonradiological Data Summary for Surface Water Location SW29
Upstream Ohio River

Analysis	Units	Minimum	Maximum	Average	Count
Chloride	mg/L	4.8	20.4	10.36	19
Fluoride	mg/L	0.1	0.17	0.1125	12
Hardness as CaCO ₃	mg/L CaCO ₃	76	116	100.71	7
Nitrate as Nitrogen	mg/L	1	1.3	1.025	12
Phosphate as P	mg/L	ND	ND	ND	12
Sulfate	mg/L	11.8	40.4	21.442	12
Hexavalent Chromium	mg/L	ND	ND	ND	12
Aluminum	mg/L	0.5	1.35	0.8521	7
Cadmium	mg/L	ND	ND	ND	7
Chromium	mg/L	ND	ND	ND	7
Copper	mg/L	ND	ND	ND	7
Iron	mg/L	0.251	1.67	0.9194	7
Lead	mg/L	0.0009	0.002	0.0013	6
Nickel	mg/L	ND	ND	ND	7
Phosphorus (P)	mg/L	0.1	0.2	0.1457	7
Zinc	mg/L	ND	ND	ND	7
BOD	mg/L	5	12	6.7143	7
pH	SU	6.4	9.3	7.7293	15
Temperature	F	45	80	62.167	6
Total Suspended Solids	mg/L	13	53	26.143	7
PCB	µg/L	ND	ND	ND	7
1,2 Dichloroethane	ug/L	1	3	1.4211	7
Acetone	ug/L	ND	ND	ND	7
Bromodichloromethane	ug/L	5	14	7	9
Chloroform	ug/L	11	41	16.083	12
Dibromochloromethane	ug/L	5	5	5	1
Isopropanol	ug/L	ND	ND	ND	7
Trichloroethene	µg/L	ND	ND	ND	7

Table 5.3 1997 Nonradiological Data Summary for Surface Water Location SW10
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count
Chloride	mg/L	23.8	78.7	36.94	7
Hardness as CaCO ₃	mg/L CaCO ₃	77	105	90.571	7
Aluminum	mg/L	0.5	1.4	0.7467	7
Cadmium	mg/L	ND	ND	ND	7
Chromium	mg/L	ND	ND	ND	7
Copper	mg/L	ND	ND	ND	7
Iron	mg/L	0.2	1.37	0.6949	7
Lead	mg/L	0.0008	0.002	0.0012	6
Nickel	mg/L	ND	ND	ND	7
Phosphorus (P)	mg/L	0.18	0.37	0.2586	7
Zinc	mg/L	ND	ND	ND	7
BOD	mg/L	5	9	5.8571	7
Flow	MGD	0.247	9.6	1.1781	38
pH	SU	7	8.95	7.6611	44
Temperature	F	40	80	60.167	6
Total Suspended Solids	mg/L	10	20	13.286	7
PCB	ug/L	ND	ND	ND	7
Acetone	ug/L	ND	ND	ND	7
Isopropanol	ug/L	ND	ND	ND	7
Trichloroethene	μg/L	ND	ND	ND	7

Table 5.4 1997 Nonradiological Data Summary for Surface Water Location SW5
Downstream Big Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count
Chloride	mg/L	34.6	104	50.757	7
Hardness as CaCO ₃	mg/L CaCO ₃	113	234	157.43	7
Aluminum	mg/L	ND	ND	ND	7
Cadmium	mg/L	ND	ND	ND	7
Chromium	mg/L	ND	ND	ND	7
Copper	mg/L	ND	ND	ND	7
Iron	mg/L	0.201	0.423	0.2843	7
Lead	mg/L	0.0008	0.0104	0.0028	6
Nickel	mg/L	ND	ND	ND	7
Phosphorus (P)	mg/L	0.1	0.34	0.1829	7
Zinc	mg/L	ND	ND	ND	7
BOD	mg/L	5	14	6.8571	7
Flow	MGD	0.293	14.6	6.3956	38
pH	SU	6.83	9.14	7.7614	44
Temperature	F	40	80	60.333	6
Total Suspended Solids	mg/L	4	12	9.8571	7
PCB	µg/L	ND	ND	ND	7
Acetone	µg/L	ND	ND	ND	7
Isopropanol	µg/L	ND	ND	ND	7
Trichloroethene	µg/L	ND	ND	ND	3

Table 5.5 1997 Nonradiological Data Summary for Surface Water Location SW64
Massac Creek

Analysis	Units	Minimum	Maximum	Average	Count
Chloride	mg/L	7.6	15.3	11.614	7
Hardness as CaCO ₃	mg/L CaCO ₃	41	81	56.143	7
Aluminum	mg/L	ND	ND	ND	7
Cadmium	mg/L	ND	ND	ND	7
Chromium	mg/L	ND	ND	ND	7
Copper	mg/L	ND	ND	ND	7
Iron	mg/L	0.747	1.98	1.0967	7
Lead	mg/L	0.0008	0.002	0.0011	6
Nickel	mg/L	ND	ND	ND	7
Phosphorus (P)	mg/L	ND	ND	ND	7
Zinc	mg/L	ND	ND	ND	7
BOD	mg/L	5	9	5.7143	7
Flow	MGD	0.247	9.6	1.1781	38
pH	SU	6.2	7.19	6.8817	6
Temperature	F	37	76	55.5	6
Total Suspended Solids	mg/L	10	10	10	7
PCB	ug/L	ND	ND	ND	7
Acetone	ug/L	ND	ND	ND	7
Isopropanol	ug/L	ND	ND	ND	7
Trichloroethene	ug/L	ND	ND	ND	3

Table 5.6 1997 Nonradiological Data Summary for Surface Water Location SW8
Confluence of Big and Little Bayou Creeks

Analysis	Units	Minimum	Maximum	Average	Count
Trichloroethene	g/L	ND	ND	ND	3

Table 5.7 1997 Nonradiological Data Summary for Surface Water Location SW11
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count
Chloride	mg/L	12.7	31.2	22.357	21
Hardness as CaCO ₃	mg/L CaCO ₃	66	180	94.286	14
Aluminum	mg/L	0.5	1.22	0.7817	21
Cadmium	mg/L	0.001	0.001	0.001	21
Chromium	mg/L	0.011	0.011	0.011	21
Copper	mg/L	0.01	0.012	0.011	21
Iron	mg/L	0.35	1.54	0.929	21
Lead	mg/L	0.0008	0.002	0.0012	20
Nickel	mg/L	0.1	0.1	0.1	21
Phosphorus (P)	mg/L	0.13	0.29	0.17	21
Zinc	mg/L	0.1	0.1	0.1	21
BOD	mg/L	5	7	5.5714	7
pH	SU	6.97	7.5	7.185	12
Temperature	F	34	76	56.83	6
Total Suspended Solids	mg/L	10	18	11.86	7
PCB	ug/L	<0.17	<0.17	<0.17	21
Acetone	ug/L	<1000	<1000	<1000	21
Isopropanol	ug/L	<1000	<1000	<1000	21
Trichloroethene	ug/L	<1	<1	<1	28

Table 5.8 1997 Nonradiological Data Summary for Surface Water Location SW12
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count
Trichloroethene	g/L	2	3	2.67	3

Table 5.9 1997 Data Summary for Surface Water Location SW135
Upstream C746 S&T closed Landfills

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Chloride	mg/L	2.9	36.1	13.3	15	
Sulfate	mg/L	9	33.9	18.88	15	
Total Organic Carbon	mg/L	5	18.6	12.74	15	
Iron	mg/L	0.566	2.2	1.5612	15	
Sodium	mg/L	5	19.7	7.94	15	
COD	mg/L	19	47	34.8	5	
Dissolved Solids	mg/L	87	176	142.2	5	
Suspended Solids	mg/L	10	41	26.6	5	
Total Solids	mg/L	153	252	202.6	5	
pH	SU	7.2	7.67	7.465	8	
Specific Conductance	umhos/cm	213	266	240.2	5	
Gross Alpha	pCi/L	-0.1	13	532	15	2.7
Gross Beta	pCi/L	10	89	34.2	15	6
Uranium	mg/L	0.004	0.021	0.008	20	

Table 5.10 1997 Nonradiological Data Summary for Surface Water Location SW136
At the C746 S&T closed Landfills

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Chloride	mg/L	4.5	12.3	8.12	15	
Sulfate	mg/L	15.4	35	30.52	15	
Total Organic Carbon	mg/L	7	20	12.64	15	
Iron	mg/L	0.25	1.11	0.7524	15	
Sodium	mg/L	5	6.44	5.518	15	
COD	mg/L	14	58	32.2	5	
Dissolved Solids	mg/L	98	232	185.4	5	
Suspended Solids	mg/L	10	61	30.4	5	
Total Solids	mg/L	221	252	235.2	5	
pH	SU	7.4	8	7.6425	8	
Specific Conductance	umhos/cm	235	324	300.2	5	
Gross Alpha	pCi/L	0.2	4.9	2.32	15	1.6
Gross Beta	pCi/L	7	183	49.4	15	9
Uranium	mg/L	0.001	0.009	0.0042	20	

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**Table 5.11 1997 Nonradiological Data Summary for Surface Water Location SW137
Downstream of C746 S&T closed Landfills**

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Chloride	mg/L	4.6	24.7	8.85	15	
Sulfate	mg/L	10.3	37.6	20.7	15	
Total Organic Carbon	mg/L	5	18	11.9	15	
Iron	mg/L	0.488	4.28	2.6585	15	
Sodium	mg/L	5	13.3	6.3833	15	
COD	mg/L	23	59	37.33	5	
Dissolved Solids	mg/L	100	193	145	5	
Suspended Solids	mg/L	10	93	53	5	
Total Solids	mg/L	154	240	203	5	
pH	SU	7.28	7.39	7.3175	8	
Specific Conductance	umhos/cm	144	261	198.17	5	
Gross Alpha	pCi/L	1.3	10	4.45	18	2.2
Gross Beta	pCi/L	7	100	34.833	18	7
Uranium	mg/L	0.004	0.008	0.0058	24	

**Table 5.12 1997 Nonradiological Data Summary for Surface Water Location SW150
At the C746U Landfill**

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Chloride	mg/L	2	23.4	11.62	15	
Sulfate	mg/L	12.9	37.6	23	15	
Total Organic Carbon	mg/L	5	29.8	15.28	15	
Iron	mg/L	0.341	2.88	1.2166	15	
Sodium	mg/L	5	8.88	5.776	15	
COD	mg/L	14	74	41.6	5	
Dissolved Solids	mg/L	117	198	166.4	5	
Suspended Solids	mg/L	10	133	36.8	5	
Total Solids	mg/L	178	241	211.4	5	
pH	SU	7.45	8.41	7.7725	8	
Specific Conductance	umhos/cm	158	310	243	5	
Gross Alpha	pCi/L	-2.3	6.1	1.64	15	1.7
Gross Beta	pCi/L	5	54	23.6	15	5
Uranium	mg/L	0.001	0.002	0.0012	20	

Table 5.13 1997 Nonradiological Data Summary for Surface Water Location SW154
Upstream of the C746U Landfill

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Chloride	mg/L	4.1	25.8	17.78	15	
Sulfate	mg/L	15.2	47.7	27.46	15	
Total Organic Carbon	mg/L	5	17.9	9.58	15	
Iron	mg/L	0.509	4.61	2.1558	15	
Sodium	mg/L	5	33	14.24	15	
COD	mg/L	21	58	30	5	
Dissolved Solids	mg/L	75	212	164.4	5	
Suspended Solids	mg/L	10	96	50.4	5	
Total Solids	mg/L	152	255	227.8	5	
pH	SU	7.31	7.5	7.425	8	
Specific Conductance	umhos/cm	191	329	238	5	
Gross Alpha	pCi/L	0.6	5.9	3.1	15	1.8
Gross Beta	pCi/L	10	44	28	15	4
Uranium	mg/L	0.004	0.012	0.0058	20	

Table 5.14 1997 Nonradiological Data Summary for Surface Water Location SW155
Downstream of the C746U Landfill

Analysis	Units	Minimum	Maximum	Average	Count	Max Rad Error
Chloride	mg/L	7.6	30.3	14.95	15	
Sulfate	mg/L	8.6	68.4	37	15	
Total Organic Carbon	mg/L	4	18	9.5	15	
Iron	mg/L	0.636	18.1	4.889	15	
Sodium	mg/L	6.33	36.6	15.54	15	
COD	mg/L	19	58	32.667	5	
Dissolved Solids	mg/L	123	192	162.83	5	
Suspended Solids	mg/L	10	1672	309.17	5	
Total Solids	mg/L	173	1730	475.83	5	
pH	SU	7	7.39	7.195	8	
Specific Conductance	umhos/cm	105	350	251.33	5	
Gross Alpha	pCi/L	-1.5	10.4	4.7667	18	2.6
Gross Beta	pCi/L	8	21	15	18	3
Uranium	mg/L	0.003	0.029	0.015	24	

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Table 5.15 1997 Nonradiological Data Summary for Surface Water Location SW241
Downstream Little Bayou Creek

Analysis	Units	Minimum	Maximum	Average	Count
Trichloroethene	g/L	26	32	28.5	4

Table 5.16 1997 Nonradiological Sediment Data Summary

Station	Analysis	Result	Units	Station	Analysis	Result	Units
SS1	Total Organic Carbon	810	mg/kg	SS27	Total Organic Carbon	330	mg/kg
SS1	Aluminum	1790	mg/kg	SS27	Barium	9.42	mg/kg
SS1	Barium	12.8	mg/kg	SS27	Calcium	150	mg/kg
SS1	Calcium	302	mg/kg	SS27	Chromium	79.7	mg/kg
SS1	Chromium	19.4	mg/kg	SS27	Copper	7.02	mg/kg
SS1	Copper	6	mg/kg	SS27	Iron	4400	mg/kg
SS1	Iron	8200	mg/kg	SS27	Magnesium	63.8	mg/kg
SS1	Magnesium	156	mg/kg	SS27	Manganese	38.1	mg/kg
SS1	Manganese	136	mg/kg	SS27	Vanadium	15.1	mg/kg
SS1	Vanadium	17.7	mg/kg	SS27	Zinc	22.5	mg/kg
SS2	Total Organic Carbon	1500	mg/kg	SS28	Total Organic Carbon	240	mg/kg
SS2	Arsenic	6.09	mg/kg	SS28	Barium	7	mg/kg
SS2	Barium	88.2	mg/kg	SS28	Chromium	6.13	mg/kg
SS2	Calcium	1010	mg/kg	SS28	Magnesium	54.1	mg/kg
SS2	Chromium	65.9	mg/kg	SS28	Manganese	99.2	mg/kg
SS2	Cobalt	16.2	mg/kg	SS21	Total Organic Carbon	2400	mg/kg
SS2	Copper	8.66	mg/kg	SS21	Arsenic	27.2	mg/kg
SS2	Iron	27150	mg/kg	SS21	Barium	126	mg/kg
SS2	Lead	26.2	mg/kg	SS21	Beryllium	3.54	mg/kg
SS2	Magnesium	390	mg/kg	SS21	Calcium	14560	mg/kg
SS2	Manganese	1160	mg/kg	SS21	Chromium	126	mg/kg
SS2	Nickel	7.41	mg/kg	SS21	Cobalt	25	mg/kg
SS2	Vanadium	44.4	mg/kg	SS21	Copper	20.8	mg/kg
SS2	Zinc	57.4	mg/kg	SS21	Iron	79370	mg/kg
SS21	Total Organic Carbon	2300	mg/kg	SS21	Lead	52.9	mg/kg
SS20	Barium	11.6	mg/kg	SS21	Magnesium	1650	mg/kg
SS20	Calcium	179	mg/kg	SS21	Manganese	2830	mg/kg
SS20	Chromium	8.29	mg/kg	SS21	Nickel	28.4	mg/kg
SS20	Magnesium	85.8	mg/kg	SS21	Potassium	315	mg/kg
SS20	Manganese	152	mg/kg	SS21	Sodium	462	mg/kg
SS20	Vanadium	17.8	mg/kg	SS21	Titanium	66.9	mg/kg

Table 5.17 Historical Nonradiological Sediment Sampling Results ($\mu\text{g}/\text{kg}$) for PCBs

Year	<i>Station</i>					
	SS1	SS2	SS20	SS21	SS27	SS28
1993	300	20,000	<100	<100		
1994	100	1400	<100	<100		
1995	<100	<100	<100	<100		
1996	<100	133	<100	<100	<100	<100
1997	<100	<100	<100	<100	<100	<100

Conversions

<i>Multiply</i>	<i>by</i>	<i>to obtain</i>	<i>Multiply</i>	<i>by</i>	<i>to obtain</i>
in	2.54	centimeters	centimeters	0.394	in
ft	0.305	m	m	3.28	ft
mile	1.61	km	km	0.621	mile
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
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)