2018 Paducah Site
Annual Site Environmental Report

FRNP-RPT-0083

This report is intended to fulfill the requirements of U.S. Department of Energy Order (DOE) 231.1B. The data and information contained in this report were collected in accordance with the Paducah Site Environmental Monitoring Plan (FRNP 2018a) approved by DOE. This report is not intended to provide the results of all sampling conducted at the Paducah Site. Additional data collected for other site purposes, such as environmental restoration, remedial investigation reports, and waste management characterization sampling, are presented in other documents that have been prepared in accordance with applicable DOE guidance and/or federal or state laws.

FRNP-RPT-0083

Paducah Site
Annual Site Environmental Report
for Calendar Year 2018

February 2020

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

Prepared by
FOUR RIVERS NUCLEAR PARTNERSHIP, LLC,
managing the
Deactivation and Remediation Project at the
Paducah Gaseous Diffusion Plant
under Contract DE-EM0004895

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ACRONYMS

AFV	alternative fuel vehicle
ALARA	as low as reasonably achievable
BCG	biota concentration guide
CAAS	criticality accident alarm system
CAP-88	Clean Air Act Assessment Package-1988 Version 4
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CY	calendar year
DCS	derived concentration technical standard
DOE	U.S. Department of Energy
DOECAP-AP	DOE Consolidated Audit Program-Accreditation Program
DUF_6	depleted uranium hexafluoride
EMS	Environmental Management System
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ERPP	Environmental Radiation Protection Program
FFA	Federal Facility Agreement
FR	*Federal Register*
FRNP	Four Rivers Nuclear Partnership, LLC
FY	fiscal year
HSWA	Hazardous and Solid Waste Amendments
KAR	*Kentucky Administrative Regulations*
KDAQ	Kentucky Division for Air Quality
KDEP	Kentucky Department for Environmental Protection
KDOW	Kentucky Division of Water
KDWM	Kentucky Division of Waste Management
KPDES	Kentucky Pollutant Discharge Elimination System
MCS	Mid-America Conversion Services, LLC
N/A	not applicable
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NOV	notice of violation
OREIS	Oak Ridge Environmental Information System
PEGASIS	PPPO Environmental Geographic Analytical Spatial Information System
PEMS	Project Environmental Measurements System
PGDP	Paducah Gaseous Diffusion Plant
PPPO	Portsmouth/Paducah Project Office
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RGA	Regional Gravel Aquifer
SPCC	spill prevention, control, and countermeasure
SST	Swift & Staley Inc.
SWMU	solid waste management unit
TCLP	Toxicity Characteristic Leaching Procedure
TLD	thermoluminescent dosimeter
TRE	Toxicity Reduction Evaluation

VOC	volatile organic compound
WKWMA	West Kentucky Wildlife Management Area

REQUEST FOR COMMENTS

The U.S. Department of Energy (DOE) requires an annual site environmental report from each of the sites operating under its authority. This report presents the results from the various environmental monitoring programs and activities carried out during the year. This *Paducah Site Annual Site Environmental Report for Calendar Year 2018* was prepared to fulfill DOE requirements. This report is a public document that is distributed to government regulators, businesses, special interest groups, and members of the public.

This report is based on thousands of environmental samples collected at or near the Paducah Site. Significant efforts were made to provide the data collected and details of the site environmental management programs in a clear and concise manner. The editors of this report encourage comments in order to better address the needs of our readers in future site environmental reports. You can complete a comment form online using the following link:

https://form.jotform.com/81494625478166

If you prefer, written comments may be sent to the following address:

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

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EXECUTIVE SUMMARY

The U.S. Department of Energy (DOE) manages work at the Paducah Site to comply with and adhere to applicable laws, regulations, and site-specific regulatory permits. References in this report to the Paducah Site generally mean the property, programs, and facilities at or near Paducah Gaseous Diffusion Plant (PGDP) for which DOE has ultimate responsibility. DOE continues to implement projects in a manner that protects site personnel, the environment, and the community and strives to maintain full compliance with current environmental regulations. The U.S. Environmental Protection Agency, Region 4, primarily provides oversight of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cleanup activities at the Paducah Site. The Kentucky Department for Environmental Protection also oversees CERCLA cleanup at the Paducah Site as well as issues regulatory permits and oversees compliance with applicable environmental laws and regulations for which they have implementation authority. These agencies issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable laws and regulations.

The purpose of this Annual Site Environmental Report is to summarize calendar year 2018 environmental management activities at the Paducah Site, including effluent monitoring, environmental surveillance, and environmental compliance status and to highlight significant site program efforts. Annually, DOE implements programs at the Paducah Site to measure any impacts that its operations have on the environment or the public. Surveillance under these programs includes analyses of surface water, groundwater, sediment, ambient air, and direct radiation.

DOE and its contractors are committed to enhancing environmental stewardship and to reducing any impacts that site operations may cause to the environment. The Paducah Site implements sound stewardship practices in the protection of land, air, water, and other natural or cultural resources potentially impacted by their operations. An environmental stewardship scorecard assesses agency performance under the Environmental Management System. The environmental stewardship scorecard for the Paducah Site in fiscal year 2018 was green, which indicates standards for the Environmental Management System implementation have been met.

Groundwater programs continue to remediate contamination in off-site groundwater plumes and on-site source areas. Ambient air monitoring contaminant levels continue either to be not detected or be detected below permitted limits. The internal/external dose of radiation (based on calculations) that could be received by a member of the public is 5.1 millirem/year, or 1/19 of the DOE annual dose limit (the DOE annual dose limit to members of the public is 100 millirem/year).

DOE continues to implement the environmental cleanup program at the Paducah Site. Highlights of accomplishments during 2018 include the following: removed approximately 131 gal of trichloroethene from the Northeast and Northwest groundwater plumes; continued to optimize the Paducah Site's infrastructure to conserve energy/water and reduce utility costs; converted approximately 5,366 metric tons of depleted uranium hexafluoride to a more stable oxide and hydrofluoric acid; and reused, recycled, or diverted approximately 208 tons of materials. DOE continued stabilization and deactivation projects at the Paducah Site that involve isolating utilities, removal and compliant disposition of hazardous materials from facilities, and removal of radiological material to ready the facilities for demolition. In 2018, DOE placed approximately 1,077 tons of solid waste into the Kentucky Division of Waste Management-permitted solid waste landfill at the Paducah Site.

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1. INTRODUCTION

The U.S. Department of Energy (DOE) requires that environmental monitoring be conducted and documented for its facilities under the purview of DOE Order 231.1B, *Environment, Safety, and Health Reporting*. Several other laws, regulations, and DOE directives require compliance with environmental standards. The purpose of this Annual Site Environmental Report is to summarize calendar year (CY) 2018 environmental management activities at the Paducah Site, including effluent monitoring and environmental surveillance, environmental compliance status, and to highlight significant site program efforts. References in this report to the Paducah Site generally mean the property, programs, and facilities at or near Paducah Gaseous Diffusion Plant (PGDP) for which DOE has ultimate responsibility. Several documents are referenced within this report; where available, electronic hyperlinks to the documents are provided.

Environmental monitoring consists of the following two major activities: (1) effluent monitoring and (2) environmental surveillance. Effluent monitoring is the direct measurement or the collection and analysis of samples of liquid and gaseous discharges to the environment. At the Paducah Site, environmental surveillance is the direct measurement or the collection and analysis of samples consisting of ambient air, surface water, groundwater, and sediment. Effluent monitoring and environmental surveillance are performed to characterize and quantify contaminants, assess radiation exposure, demonstrate compliance with applicable standards and permit requirements, and detect and assess the effects, if any, on the local population and environment. Samples are collected throughout the year and are analyzed for radioactivity, chemical constituents, and various physical properties.

The overall goals for DOE Environmental Management are to protect site personnel, the environment, and the community and to maintain full compliance with all current applicable environmental regulations. DOE operates the Paducah Site in a manner that controls and reduces exposures of the public, workers, and the environment to harmful chemicals and radiation.

Prime contractors performing work to support DOE missions at the Paducah Site include the following: Mid-America Conversion Services, LLC (MCS); Swift & Staley Inc. (SST);[1] and Four Rivers Nuclear Partnership, LLC (FRNP).

1.1 SITE LOCATION AND HISTORY

The Paducah Site is located in a generally rural area of McCracken County, Kentucky, 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River (Figure 1.1).

[1] Swift & Staley Inc. is known as SST at the Paducah Site.

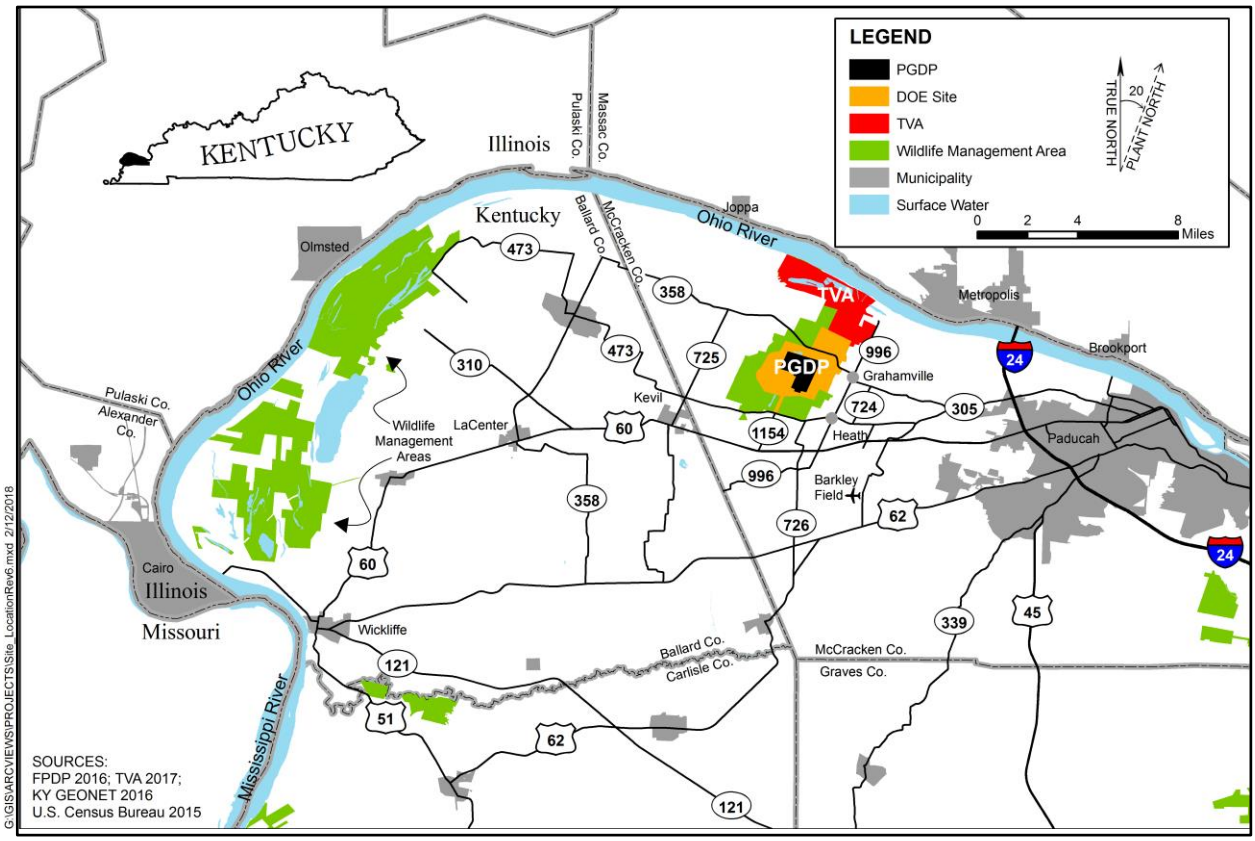

Figure 1.1. Location of the Paducah Site

The plant is on a 3,556-acre DOE site, approximately 1,986 acres of which are licensed to the Commonwealth of Kentucky as part of the West Kentucky Wildlife Management Area (WKWMA).

WKWMA consists of woodlands, meadows, and cultivated fields and is used by hunters, trappers, and anglers each year. Hunting and trapping activities may include such wildlife as rabbit, deer, quail, raccoon, squirrel, dove, turkey, waterfowl, and beaver. Additionally, the Kentucky Department of Fish and Wildlife Resources sponsors field hunting trials for dogs within the WKWMA.

During World War II, Kentucky Ordnance Works operated its main process and some storage areas in an area southwest and west of the plant on what is now WKWMA.

The plant was constructed in the early 1950s and started uranium enrichment in 1952. Until 2013, the Paducah Site was an active uranium enrichment facility. The Energy Policy Act of 1992 provided for lease of the enrichment facilities to a commercial entity that operated the enrichment facilities from 1998 to 2013. In 2014, the leased facilities were returned to DOE control, and a DOE contractor began management of the facilities for DOE. These returned facilities are undergoing deactivation in preparation for decommissioning.

1.2 GENERAL ENVIRONMENTAL SETTING

1.2.1 Climate

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

1.2.2 Surface Water Drainage

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

Flooding in the area is associated with Bayou Creek, Little Bayou Creek, and the Ohio River. Maps developed in support of the National Flood Insurance Program show a flood hazard located within the DOE boundary at the Paducah Site, but only slightly within the industrialized area of the Paducah Site (FEMA 2018). This flood hazard defines the 100-year flood line.

1.2.3 Wetlands

Approximately 1,100 separate wetlands, totaling over 1,500 acres, were found in a study area of about 12,000 acres in and around the Paducah Site (COE 1994). More than 60% of the total wetland area is forested.

1.2.4 Soils and Hydrogeology

Soils of the area are predominantly silty loams that are poorly drained, acidic, and have little organic content. The local groundwater flow system at the Paducah Site is described in Section 6.1.

1.2.5 Vegetation

Much of the Paducah Site has been impacted by human activity. Vegetation communities on the reservation are indicative of old field succession (e.g., grassy fields, field scrub-shrub, and upland mixed hardwoods). The open grassland areas, most of which are managed by WKWMA personnel, are mowed periodically or burned to maintain early successional vegetation, which is dominated by members of the *Compositae* family and various grasses. Species commonly cultivated for wildlife forage are corn, millet, milo, and soybean (CH2M HILL 1992). In 2018, corn, soybeans, and sunflowers were cultivated within the WKWMA.

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

Upland mixed hardwood communities contain a variety of upland and transitional species. Dominant species include oaks, shagbark and shellbark hickory, and sugarberry (CH2M HILL 1991). The undergrowth varies, with limited undergrowth for more mature stands of trees, to dense undergrowth similar to that described for a scrub-shrub community.

1.2.6 Wildlife

Wildlife species indigenous to hardwood forests, scrub-shrub, and open grassland communities are present at the Paducah Site. Some areas near the Paducah Site are frequented by rabbits, mice, opossum, vole, mole, raccoon, and deer. Birds include red-winged blackbirds, quail, sparrows, shrikes, mourning doves, turkeys, cardinals, meadowlarks, hawks, and owls. Several groups of coyotes also reside in these areas around the Paducah Site. Aquatic habitats are used by muskrat and beaver in the study area. A list of representative species is provided in Results of the Site Investigation Phase 1 (CH2M HILL 1991). Additionally, the Ohio River, which is 3.5 miles north of the Paducah Site, serves as a major flyway for migratory waterfowl (DOE 1995a). Harvestable fish populations exist in Bayou Creek, especially near the mouth of the creek at the Ohio River. Fish populations in Little Bayou Creek are in the minnow category (DOE 2018a).

1.2.7 Threatened and Endangered Species

A threatened and endangered species investigation identified federally listed, proposed, or candidate species potentially occurring at or near the Paducah Site (COE 1994). Updated information is obtained on a regular basis from federal and Commonwealth of Kentucky sources. Currently, potential habitat for 16 species of federal concern exists in the study area. Fourteen of these species are listed as "endangered" under the Endangered Species Act of 1973, and two are "threatened" (Chapter 2, Table 2.3). While there are potential habitats for endangered species on DOE property, none of the federally listed or candidate species has been found on DOE property at the Paducah Site.

1.3 SITE MISSION

DOE established the Portsmouth/Paducah Project Office (PPPO) on October 1, 2003, to provide focused leadership to the environmental management missions at the Portsmouth, Ohio, and Paducah, Kentucky, gaseous diffusion plants.

The PPPO Lexington, Kentucky, office opened in January 2004, and is located midway between the Kentucky and Ohio facilities. Although the PPPO manager is located in the Lexington office, frequent and routine site interactions occur by this office at both the Portsmouth and Paducah Sites. Additionally, DOE maintains a strong presence at the sites on a daily basis through its Portsmouth and Paducah Site offices. The mission of the PPPO is to conduct the safe, secure, compliant, and cost-effective environmental cleanup of the Portsmouth and Paducah Uranium Enrichment Sites on behalf of the local communities and the American taxpayers.

In addition to gaseous diffusion plant stabilization, deactivation, and infrastructure management, DOE's PPPO mission is to accomplish the following at the Portsmouth and Paducah Sites (http://energy.gov/pppo/pppo-mission).

- Environmental Remediation
- Waste Management
- Depleted Uranium Hexaflouride (DUF_6) Conversion
- Decontamination and Decommissioning

1.4 PRIMARY OPERATIONS AND ACTIVITIES AT THE PADUCAH SITE

The Paducah Site is shown in Figure 1.2. The following two major programs are operated by DOE at the Paducah Site: (1) Environmental Management and (2) Uranium Program.

Figure 1.2. DOE Paducah Site at Sunrise

The Environmental Management Program includes Environmental Restoration; Facility Stabilization, Deactivation, Infrastructure Optimization; and Waste Management projects. Additional information regarding these activities is found in Section 3.1.

- The mission of the Environmental Restoration Project is to ensure that releases from past operations at the Paducah Site are investigated and that appropriate response actions are taken for protection of human health and the environment in accordance with the Federal Facility Agreement (FFA) (EPA 1998).

- The mission of Facility Stabilization, Deactivation, and Infrastructure Optimization is to remove radioactive and hazardous materials from the facility, safely shut down facility systems, and optimize infrastructure that will continue to support the site.

- The mission of the Waste Management Project is to characterize and dispose of waste stored and generated on-site in compliance with regulatory requirements and DOE Orders.

- The mission of Decontamination and Demolition is to tear down the former gaseous diffusion plant and support facilities and dispose of the demolition debris in compliance with regulatory requirements and DOE Orders.

The major missions of the Uranium Program are to maintain safe compliant storage of the DOE DUF_6 inventory until final disposition, operation of a facility for conversion of DUF_6 to a more stable oxide and hydrofluoric acid, and to manage associated facilities and grounds.

1.5 DEMOGRAPHIC INFORMATION

The population of McCracken County, Kentucky, is approximately 65,000 (DOC 2019). The major city in McCracken County is Paducah, Kentucky, whose population is approximately 25,000 (DOC 2019). Three small communities are located within 3 miles of the DOE property boundary at the Paducah Site: Heath and Grahamville to the east and Kevil to the southwest. The closest commercial airport is Barkley Regional Airport, approximately 5 miles to the southeast. The population within a 50-mile radius of the Paducah Site is about 534,000 according to the 2010 census.

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2. COMPLIANCE SUMMARY

The U.S. Environmental Protection Agency (EPA), Region 4, primarily provides oversight of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) cleanup activities at the Paducah Site. The Kentucky Department for Environmental Protection (KDEP) also oversees CERCLA cleanup at the Paducah Site as well as issues regulatory permits and oversees compliance with applicable environmental laws and regulations for which they have implementation authority.

The EPA develops, promulgates, and enforces environmental protection regulations and technology-based standards as directed by statutes passed by the U.S. Congress. In most instances, EPA has delegated regulatory authority to KDEP when the Kentucky program meets or exceeds EPA requirements.

2.1 ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

2.1.1 Comprehensive Environmental Response, Compensation, and Liability Act

DOE and EPA Region 4 entered into an Administrative Consent Order in August 1988 under Sections 104 and 106 of CERCLA. The Administrative Consent Order was in response to the off-site groundwater contamination detected at the Paducah Site in July 1988.

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

Section 120 of CERCLA requires federal agencies with facilities on the National Priorities List to enter into an FFA with the EPA. The FFA, which was signed February 13, 1998, by DOE, EPA, and KDEP, established a decision making process for remediation of the Paducah Site and coordinates CERCLA remedial action requirements with Resource Conservation and Recovery Act (RCRA) corrective action requirements. DOE, EPA, and KDEP agreed to terminate the CERCLA Administrative Consent Order because those activities could be continued under the FFA. The FFA, a three-party agreement among DOE, EPA, and KDEP, defines the process for all remediation activities undertaken at the Paducah Site. The FFA contains requirements for implementing investigations; selection and implementation of appropriate remedial and removal actions; and establishing priorities for action and development of schedules, consistent with priorities, goals, and objectives of the agreement.

Significant milestones completed under CERCLA and the FFA for CY 2018 at the Paducah Site are included in Table 2.1.

2.1.2 Superfund Amendments and Reauthorization Act

The Superfund Amendments and Reauthorization Act amended CERCLA on October 17, 1986. The Act reflected EPA's experience in administering the complex Superfund program and made several important changes and additions to the program. Changes of particular importance are (1) increased the focus on human health problems posed by hazardous waste sites, and (2) encouraged greater citizen participation in making decisions on how sites should be cleaned up. DOE utilizes various methods to engage citizen participation in cleanup decision making for the Paducah Site. These programs are described in Section 3.2.

Table 2.1. CERCLA FFA Significant Milestones Completed in CY 2018

Document/Activity	Date Due	Date Completed
Burial Grounds Operable Unit Solid Waste Management Unit (SWMU) 4 Feasibility Study D2/R1	3/30/2018	3/26/2018
Interim Remedial Action Completion Report for C-400 D2	7/6/2018	7/2/2018
Northeast Plume Postconstruction Report D2/R1	7/1/2018	6/28/2018
FFA Community Relations Plan D2	11/23/2018	11/20/2018
CERCLA Waste Disposal Alternative Remedial Investigation/Feasibility Study Report D2/R2	7/7/2018	7/2/2018
C-400 Remedial Investigation/Feasibility Study Work Plan D1	11/28/2018	11/19/2018
C-400 Demolition Removal Notification D1	3/1/2018	1/10/2018
C-400 Demolition Engineering Evaluation/Cost Analysis D1	5/2/2018	5/2/2018
C-400 Demolition Action Memorandum D1	8/14/2018	6/21/2018
C-400 Demolition Removal Action Work Plan D1	8/17/2018	8/16/2018

2.1.3 Resource Conservation and Recovery Act

Regulatory standards for the characterization, treatment, storage, and disposal of solid and hazardous waste are established by RCRA. Waste generators must follow specific requirements outlined in RCRA regulations for handling solid and hazardous wastes. Owners and operators of hazardous waste treatment, storage, and disposal facilities are required to obtain operating and/or postclosure permits for waste treatment, storage, and disposal activities. The Paducah Site generates solid waste, hazardous waste, and mixed waste (i.e., hazardous waste mixed with radionuclides) and operates three permitted hazardous waste storage and treatment facilities (C-733, C-746-Q, and C-752-A). The closed C-404 Hazardous Waste Landfill also is managed under requirements of the RCRA regulations and permit.

2.1.4 Resource Conservation and Recovery Act Hazardous Waste Permit

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

The current hazardous waste facility permit was issued by the Kentucky Division of Waste Management (KDWM) to DOE in July 2015 and became effective on August 23, 2015. The federal portion of the hazardous waste facility permit is known as a Hazardous and Solid Waste Amendments Permit. The Hazardous and Solid Waste Amendments (HSWA) permit contains federal permit conditions for all HSWA provisions applicable to the Paducah facility for which KDWM is not yet authorized. On April 3, 2019, KDWM received final authorization from EPA for certain HSWA provisions, including organic air emission standards and land disposal restrictions. As a result, applicable HSWA requirements will be met through the KDWM hazardous waste facility permit, and renewal of the HSWA permit will not be necessary.

DOE is required to report compliance issues as part of the annual Hazardous Waste Report submittal to KDWM. In 2018, three issues were reported. The first issue was related to the plant pump houses associated with the cooling towers that previously had operated as part of the enrichment facilities. Residual materials were found in the diked areas underneath sulfuric acid and phosphoric acid tanks associated with these pump houses. Sample results showed that the materials from some of the areas contained concentrations

that exceeded the Toxicity Characteristic Leaching Procedure (TCLP) limits for one or more analytes, indicating it was hazardous waste. The waste was contained inside the diked areas; however, because it was not containerized and not stored within an approved hazardous waste storage area, this issue was reported to KDWM. Upon receipt of these results, the waste was removed, containerized, and placed into compliant storage. No evidence of a release to the environment was found.

The second compliance issue that was reported pertained to groundwater sampling activities that are required for the C-404 Hazardous Waste Landfill. Quality control is measured by collecting duplicate samples on a specified frequency. Although duplicate samples were being collected as specified by procedure and industry standard, it was identified that sample collection for the duplicate samples was not being performed as described in Hazardous Waste Management Facility Permit. Since this issue was identified in May 2018, DOE has been collecting two duplicate samples, one by each of the two methods, until a permit modification can be completed to clarify which method is to be used.

The third compliance issue stemmed from two separate waste shipments sent from the Paducah Site to Energy*Solutions* in Clive, Utah. The first shipment of waste, fifty-five 55-gal drums of low-level waste, was sent on September 26, 2018. Energy*Solutions* performs routine, random independent sampling of waste shipments. Data from the sampling for this shipment identified that a portion of the drums exceeded the TCLP limits for one or more analytes, indicating the contents of those drums were hazardous low-level waste. The second shipment of waste, six 55-gal drums of low-level waste, was sent on November 27, 2018. Energy*Solutions* sampling data indicated that one drum from this shipment exceeded the TCLP limit for one analyte, also indicating this drum's contents was hazardous low-level waste. To address these two issues, shipping paperwork was updated to reflect that these waste drums were identified as hazardous low-level waste. Additionally, site procedures have been modified to require additional information be included in the document package prepared by waste engineers so that the managers who review the waste determinations have additional details to verify that the correct designations have been made for the waste streams prior to shipment.

As a result of the issues for the first shipment made on September 26, 2018, The State of Utah issued a Notice of Violation (NOV) for failure to provide the required Uniform Hazardous Waste Manifest. The actions described above were sufficient to respond to the NOV and on May 10, 2019, the Utah Division of Waste Management and Radiation Control stated that they considered the matter closed due to the corrective actions taken to rectify the deficiencies. No NOV has been received for the second shipment described above.

2.1.5 Federal Facility Compliance Act—Site Treatment Plan

The Federal Facility Compliance Act was enacted in October 1992. This act waived the immunity from fines and penalties that had existed for federal facilities for violations of hazardous waste management, as defined by RCRA. It also contained provisions for the development of site treatment plans for the treatment of DOE mixed waste and for the approval of such plans by the Commonwealth of Kentucky. As a result of the complex issues and problems associated with the treatment of low-level hazardous and radioactive waste (mixed waste), DOE and KDEP signed, after consideration of stakeholder input, an Agreed Order/Site Treatment Plan on September 10, 1997. The Site Treatment Plan facilitates compliance with the Federal Facility Compliance Act. For the reporting period January 1 to December 31, 2018, no addition of mixed low-level waste was added to the Site Treatment Plan (DOE 2019a).

The Agreed Order requires that DOE implement a Waste Minimization and Pollution Prevention Awareness Program to minimize the amount of new wastes added to the Site Treatment Plan each year. All projects at the Paducah Site are evaluated for waste minimization/pollution prevention opportunities. Waste minimization/pollution prevention goals include the following:

- Reducing the quantity of wastes generated at their sources;
- Draining, decanting, drying, dewatering, evaporating, and otherwise removing liquid from wastes when possible;
- Segregating, sorting, consolidating, and reducing the volume of like wastes; and
- Reusing or recycling materials.

Waste minimization/pollution prevention activities at the Paducah Site are listed in Chapter 3.

2.1.6 National Environmental Policy Act

An evaluation of the potential environmental impact of certain proposed federal activities is required by the National Environmental Policy Act (NEPA). In addition, an examination of alternatives to certain proposed actions is required. Compliance with NEPA, as administered by DOE's NEPA Implementing Procedures (10 *CFR* Part 1021) and the Council on Environmental Quality Regulations (40 *CFR* Parts 1500–1508), ensures that consideration is given to environmental values and factors in federal planning and decision making. In accordance with 10 *CFR* Part 1021, the Paducah Site conducts NEPA reviews for proposed non-CERCLA actions and determines if any proposal requires preparation of an environmental impact statement, an environmental assessment, or is a categorical exclusion from preparation of either an environmental impact statement or an environmental assessment. The Paducah Site maintains records of all NEPA reviews.

PPPO initiated an environmental assessment in 2012 to assess the environmental impacts associated with potential transfer of the Paducah Site real property to third parties for possible economic development. On December 14, 2015, DOE issued a Finding of No Significant Impact. A link to the final environmental assessment and finding is found below.[2]

PPPO initiated a supplemental environmental impact assessment in 2018 to assess the environmental impacts associated with transportation and disposal of uranium oxide produced from the conversion of DUF_6 in DOE inventory. DOE will issue the assessment upon completion.

A categorical exclusion was approved for demolition of support buildings. Numerous minor activities conducted in 2018, such as routine maintenance, small-scale facility modifications, site characterization, facility deactivation, and utility consolidation, were within the scope of an approved environmental impact statement, environmental assessment, or categorical exclusions. The DOE Paducah Site Office and the PPPO NEPA compliance officer approve and monitor the internal applications of previously approved categorical exclusion determinations.

In accordance with Section II.E of the June 13, 1994, DOE Secretarial Policy Statement on NEPA, preparation of separate NEPA documents for environmental restoration activities conducted under CERCLA no longer is required. Instead, the DOE CERCLA process incorporates NEPA values. The NEPA values encompass environmental issues that affect the quality of the human environment. Documentation of NEPA values in CERCLA documents allows the decision makers to consider the potential effects of proposed actions on the human environment. Actions conducted under CERCLA (with respect to

[2] http://www.energy.gov/pppo/downloads/paducah-gaseous-diffusion-plant-final-environmental-assessment-potential-land-and.

Environmental Restoration, Waste Disposition, and Deactivation and Decommissioning) are discussed in Chapter 3 of this report.

2.1.7 Toxic Substances Control Act

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

The Paducah Site complies with PCB regulations (40 *CFR* Part 761) and the Modification to the February 20, 1992, Compliance Agreement between DOE and EPA for the Toxic Substances Control Act. The Compliance Agreement between DOE and EPA for the Toxic Substances Control Act went into effect on February 20, 1992 (EPA 1992); subsequently it was modified on September 25, 1997 (BJC 1998), and it was modified again on May 30, 2017 (EPA 2017). The most prominent revisions to the agreement effective May 30, 2017, include the following: (1) creation of an annual meeting between PPPO and EPA, along with generation of an Integrated Schedule and a Long-Term Schedule to support the annual meeting; (2) alteration of the frequency and timing of air sampling in the process buildings; (3) update of the approach to the regulatory one-year storage requirement associated with PCBs and PCB items; and (4) modifications pertaining to management of building demolition waste, building slabs, building demolition waste that is to be processed for disposal, and other PCB wastes removed prior to a building's demolition. The major activities performed in 2018 are documented in the Annual Compliance Agreement Report for the Paducah Gaseous Diffusion Plant (FRNP 2019a) and the PCB Annual Document (FRNP 2019b).

2.2 RADIATION PROTECTION

The Atomic Energy Act of 1954 provides authority to DOE to implement DOE Order 458.1, *Radiation Protection of the Public and the Environment*, and DOE Order 435.1, *Radioactive Waste Management*. These orders establish requirements for protection of the public and the environment against any undue risk associated with radiological activities and ensures radioactive waste management is conducted in a safe manner that is protective of the worker, public, and the environment. Authorized Limits have been approved for a KDWM-permitted solid waste landfill at the Paducah Site and for DOE-owned property outside the Limited Area. DOE uses these Authorized Limits to establish concentrations or quantities of residual radioactive material that are protective of human health and the environment and are allowed on or within waste to be disposed of in landfills, on or within materials to be reused by the public, or on land and buildings to be transferred to the public. Additionally, Authorized Limits for lube oil and transformer oil have been approved by DOE for thermal destruction at Clean Harbors in Deer Park, Texas, and Veolia in Port Arthur, Texas. Authorized Limits also have been approved for unrestricted release of aqueous hydrofluoric acid generated during DUF_6 conversion operations for reuse; for shipping low-level waste to Waste Control Specialists, LLC, RCRA Landfill; and for disposal of waste containing residual radioactive materials at the Energy*Solutions* Carter Valley Landfill, Tennessee.

ALARA means "**as low as reasonably achievable**," which is an approach to radiation protection to manage and control releases of radioactive material to the environment, the workforce, and members of the public so that levels are as low as reasonably achievable, taking into account societal, environmental, technical, economic, and public policy considerations. ALARA is not a specific release or dose limit, but a process that has the goal of optimizing control and managing release of radioactive material to the environment and doses so they are as far below the applicable limits as reasonably achievable. ALARA optimizes radiation protection.

These authorized limits implement DOE Order 458.1 and ensure that doses to the public meet DOE standards and are ALARA, that groundwater is protected, that future remediation would not be needed, and that no radiological protection requirements are violated.

The Paducah Site complies with DOE Order 435.1 and DOE Order 458.1. The programs described below outline ways the Paducah Site complies with these DOE Orders.

2.2.1 DOE Order 458.1, Radiation Protection of the Public and the Environment

To help ensure compliance with the requirements of DOE Order 458.1 for the Paducah Site, DOE contractors implement an Environmental Radiation Protection Program (ERPP) (FRNP 2018b). The goals of the ERPP are as follows:

(1) To conduct radiological activities so that exposure to members of the public is maintained within the dose limits established by the Order;

(2) To control the radiological clearance of real and personal property (see "clearance of property" in glossary);

(3) To ensure that potential radiation exposures to members of the public are ALARA;

(4) To monitor routine and nonroutine radiological releases and to assess the radiation dose to members of the public; and

(5) To protect the environment from the effects of radiation and radioactive material.

2.2.2 DOE Order 435.1, Radioactive Waste Management

The Paducah Site manages low-level and transuranic waste, if produced, in compliance with DOE Order 435.1 using a number of storage and disposal units. Procedures utilized for management of these wastes ensure compliance with this Order. The quality assurance (QA) programs in place (see Chapter 7) ensure compliance with these procedures.

2.3 AIR QUALITY AND PROTECTION

2.3.1 Clean Air Act

Authority for enforcing compliance with the Clean Air Act and subsequent amendments resides with EPA Region 4 and/or the Kentucky Division for Air Quality (KDAQ). The Paducah Site complies with federal and Commonwealth of Kentucky rules by implementing the Clean Air Act and its amendments. The Paducah Site includes two separate programs that require air permitting. The Environmental Remediation, Waste Management and Decontamination and Decommissioning missions (identified as the Deactivation and Remediation Project) are combined under one air permit and the UF_6 Conversion mission is on a separate air permit.

The Deactivation and Remediation Project has identified the potential emission of hydrogen fluoride, a hazardous air pollutant, in excess of 10 tons per year. KDAQ considers the project to be major source requiring the project to maintain a Title V Air Permit.

CERCLA response actions also were a source of air emissions in 2018. Activities performed as part of CERCLA projects (e.g., groundwater treatment systems) are not subject to the Title V Air Permit. Instead of being permitted under the Clean Air Act, the substantive requirements of the Clean Air Act for the emissions associated with these CERCLA actions are applied to the actions as applicable or relevant and appropriate. Groundwater pump and treat systems at the Paducah Site remove trichloroethene (TCE) and other volatile organic compound (VOC) contamination from the groundwater by air stripping. For the Northwest Plume Groundwater Treatment System, the off-gas from the air stripper then passes through a carbon adsorption system to remove the TCE prior to atmospheric discharge. For the Northeast Plume Containment System, concentrations of TCE are sufficiently low that a carbon adsorption system is not required to keep emissions below regulatory levels.

The DUF_6 Conversion facility has the potential to emit more than 10 tons per year of hydrogen fluoride, but the DUF_6 air permit limits potential hydrogen fluoride emissions to less than 10 tons per year. As such, KDAQ considers DUF_6 facility to be a conditional major source that requires a Conditional Major Operating Air Permit.

In April 2018, EPA conducted a compliance monitoring inspection at the Paducah Site, pursuant to the Clean Air Act, Section 112(r)(7), to determine compliance with Risk Management Program regulations found at 40 *CFR* Part 68. On February 26, 2019, EPA issued notice of potential Risk Management Program violations. These potential violations are related to administrative and procedural requirements such as labeling, roles and responsibility documentation, and compliance certification. DOE has discussed these issues with EPA and modified procedures, as appropriate.

2.3.2 National Emission Standards for Hazardous Air Pollutants Program

Airborne emission of radionuclides from the Paducah Site are regulated under 40 *CFR* Part 61, Subpart H, the National Emission Standards for Hazardous Air Pollutants (NESHAP) regulations. DOE also manages radionuclide air emissions in accordance with the NESHAP Management Plan for Emission of radionuclides (FRNP 2018c). Radionuclide sources at the Paducah Site in 2018 were from deactivation projects of PGDP, DUF_6 Conversion Facility, groundwater pump-and-treat systems (Northeast Plume Containment System and Northwest Plume Groundwater Treatment System), and fugitive and diffuse sources. DOE utilized ambient air monitoring data to verify a low emission rate of radionuclides in ambient air in accordance with the NESHAP Management Plan. The fugitive and diffuse sources include building ventilation, uranium transfers, transport and disposal of waste, demolition of contaminated facilities, decontamination of contaminated equipment, and environmental remediation activities. Ambient air data were collected at nine locations surrounding the Paducah Site in order to measure radionuclides emitted from Paducah Site sources, including fugitive emissions. The ambient air results are discussed in further detail in Chapter 4.

2.4 WATER QUALITY AND PROTECTION

2.4.1 Clean Water Act

The Clean Water Act was established primarily through the passage of the Federal Water Pollution Control Act Amendments of 1972. The Clean Water Act established the following four major programs for control of water pollution:

(1) Regulating point-source and storm water discharges into waters of the United States;
(2) Controlling and preventing spills of oil and hazardous substances;
(3) Regulating discharges of dredge and fill materials into waters of the United States; and

(4) Providing financial assistance for construction of publicly owned sewage treatment works.

2.4.2 Kentucky Pollutant Discharge Elimination System

The Clean Water Act applies to all nonradiological DOE discharges to waters of the United States. At the Paducah Site, the regulations are applied through issuance of Kentucky Pollutant Discharge Elimination System (KPDES) permits for effluent discharges to Bayou Creek and Little Bayou Creek. In September 2017, the Kentucky Division of Water (KDOW) issued one consolidated KPDES Permit Number KY0004049 to DOE and FRNP for Outfalls 001, 002, 004, 006, 008, 009, 010, 011, 012, 013, 015, 016, 017,[3] 019, and 020. This permit combined outfalls that formerly were covered under both this permit and KPDES Permit KY0102083. The KPDES permit calls for monitoring as an indicator of discharge-related effects in the receiving streams. Discharge monitoring reports are issued monthly and quarterly. Additionally, the KPDES permit requires the development and implementation of a Best Management Practices Plan to prevent or minimize the potential for the release of pollutants. These Best Management Practices have requirements for all operations and are implemented through the site Environmental Management System (EMS) and work control.

During CY 2018, the site completed sampling and investigation efforts under a KDOW-approved Toxicity Reduction Evaluation Plan (TRE) due to historical acute toxicity failures at Outfall 020, which is leachate effluent from the C-746-U Landfill leachate treatment system. It was determined that the acute toxicity failures were attributed to treatment media used in the leachate treatment system. The treatment media used led to generation of ammonia in the leachate effluent, resulting in acute toxicity failures. The treatment media was replaced with one that did not impact the environment negatively. KDOW approved this completion on January 2, 2019.

During CY 2018 there were two noncompliance events related to the KPDES permit. One noncompliance was a quarterly toxicity sample at Outfall 001 that resulted in toxicity values that exceeded the chronic toxicity permit limit. In accordance with the KPDES permit, FRNP conducted a TRE for Outfall 001 to identify and address the source of toxicity. A possible source for the toxicity exceedance is believed to be turnover of the lagoon upstream of Outfall 001. Lagoon turnover is when sediment and water from the bottom rises to the surface of the lagoon, which then is discharged downstream. Retest sampling for Outfall 001 was conducted in accordance with the KPDES permit and the TRE. There were no further toxicity failures at Outfall 001 in 2018.

The second noncompliance, an exceedance of total recoverable zinc at KPDES Outfall 13, resulted in an NOV. The NOV was received on June 7, 2018. KDEP issued the NOV for failing to comply with 40 *CFR* 122.41(a), as adopted by 401 *KAR* 5:065, Section 2(1), by failing to comply with the terms and conditions of KPDES Permit No. KY0004049, Outfall K013, for total recoverable zinc. To address the exceedance, FRNP performed an evaluation of the wetland pond system upstream of Outfall K013, which resulted in the additional planting of wetland vegetation. The new plantings were added to the ditch and pond areas during October 2018. As a second action, FRNP increased surveillance of the area to ensure wetland vegetation is maintained. The completed actions have negated any exceedances of total recoverable zinc at Outfall 013. Additional information is provided in Table 2.2.

[3] Permit Number KY0004049 also includes MCS as a permittee for Outfall 017.

Table 2.2. KPDES Exceedances in CY 2018

Permit Type	Outfall	Parameter	Number of Permit Exceedances	Number of Samples Taken	Number of Compliant Samples	Percent Compliance	Month of Exceedance
KPDES (KY0004049)	013	Total recoverable zinc	1	13	12	92%	February
KPDES (KY0004049)	001	Toxicity	2*	9	7	78%	October

*These exceedances did not result in a NOV.

2.4.3 Storm Water Management and the Energy Independence and Security Act of 2007

In compliance with the Energy Independence and Security Act, the Paducah Site implements energy and water audits. These audits typically cover the building shell, lighting, possible deployment of occupancy sensors, and leaking or old water fixtures. The findings of these audits are assessed and prioritized based on the mission of the Paducah Site. A list of previous audits is presented in the Site Sustainability Plan (SST 2016).

2.4.4 Safe Drinking Water Act

The Paducah Site supplies on-site drinking water from the Ohio River to its facilities. The drinking water system was operated and managed by FRNP, in accordance with the Safe Drinking Water Act regulations for CY 2018. FRNP maintains a water withdrawal permit from KDOW for up to 30 mgd. Water is pumped from the Ohio River and treated for on-site distribution.

FRNP operates a non-community water system, regulated by KDOW. KDOW's requirement to submit monitoring plans to demonstrate compliance with regulations is applicable to the FRNP non-community water system. Various sampling locations in the FRNP non-community water system are monitored in accordance with these plans, and the monitoring results are submitted to KDOW.

2.5 OTHER ENVIRONMENTAL STATUTES

2.5.1 Endangered Species Act

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

Table 2.3 includes 16 federally listed species that have been identified as potentially occurring at or near the Paducah Site. While there are potential habitats for endangered species on DOE property, none of the federally listed or candidate species has been found on DOE property at the Paducah Site, although potential

summer habitat exists there for the Indiana Bat (Garland 2008). No DOE projects at the Paducah Site during 2018 adversely impacted any of these identified species or their potential habitats.

Table 2.3. Federally Listed Species Potentially Occurring within the Paducah Site Study Area*

Group	Common Name	Scientific Name	Endangered Species Act Status
Mammals	Gray Bat	*Myotis grisescens*	Endangered
	Indiana Bat	*Myotis sodalis*	Endangered
	Northern Long-eared Bat	*Myotis septentrionalis*	Threatened
Clams	Clubshell	*Pleurobema clava*	Endangered
	Fanshell	*Cyprogenia stegaria*	Endangered
	Fat Pocketbook	*Potamilus capax*	Endangered
	Northern Riffleshell	*Epioblasma torulosa rangiana*	Endangered
	Orangefoot Pimpleback	*Plethobasus cooperianus*	Endangered
	Pink Mucket	*Lampsilis abrupta*	Endangered
	Purple Cat's Paw	*Epioblasma obliquata obliquata*	Endangered
	Rabbitsfoot	*Quadrula cylindrica cylindrica*	Threatened
	Ring Pink	*Obovaria retusa*	Endangered
	Rough Pigtoe	*Pleurobema plenum*	Endangered
	Sheepnose Mussel	*Plethobasus cyphyus*	Endangered
	Spectaclecase	*Cumberlandia monodonta*	Endangered
Birds	Least Tern	*Sterna antillarum*	Endangered

*All of the listed species are identified as an Endangered, Threatened, or Candidate Species known or with the potential to be located near the Paducah Site within McCracken County, Kentucky, by the U.S. Fish and Wildlife Service (FWS 2019).

2.5.2 Impacts of Invasive Species

E.O. 13751, *Safeguarding the Nation from the Impacts of Invasive Species*, calls upon government agencies to take steps to prevent the introduction and spread of invasive species, and to support efforts to eradicate and control invasive species that are established. Zebra mussels are an invasive species that can be found in the two intake supply lines utilized by the Paducah Site water treatment plant. This invasive species is controlled by draining one intake supply line at a time and allowing the mussels to die and then backwashing the drained line, flushing out the mussels. DOE takes steps to minimize the spread of invasive plant species found at the Paducah Site via routine site maintenance (i.e., mowing and spraying for weeds).

2.5.3 Migratory Bird Treaty Act

The Memorandum of Understanding on Migratory Birds (2013) between DOE and the U.S. Fish and Wildlife Service and Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, direct federal agencies to take certain actions to further implement the Migratory Bird Treaty Act. The Migratory Bird Treaty Act of 1918 is applicable to the Paducah Site. DOE takes measures to minimize impacts to migratory birds by avoiding disturbance of active nests. Work control documents implement this restriction.

2.5.4 Floodplain/Wetlands Environmental Review Requirements

Title 10 *CFR* Part 1022 establishes procedures for compliance with Executive Order 11988, *Floodplain Management*, and Executive Order 11990, *Protection of Wetlands*. DOE activities did not result in significant impacts to floodplains or wetlands at the Paducah Site in 2018.

2.5.5 National Historic Preservation Act

The National Historic Preservation Act of 1966 is the primary law governing a federal agency's responsibility for identifying and protecting historic properties (cultural resources included in or eligible for inclusion in the National Register of Historic Places). Historic properties include buildings of historic significance and archeological sites. PGDP buildings were assessed in the Cultural Resources Survey (BJC 2006a). Archeological resources will be addressed as undisturbed land is developed for site use, or if undisturbed sites are considered to be impacted by DOE operations.

The Cultural Resources Management Plan identified a National Register of Historic Places-eligible historic district at the facility (BJC 2006b). The PGDP Historic District contains 101 contributing properties and is eligible for the National Register of Historic Places under National Register Criterion A for its military significance during the Cold War and for its role in commercial nuclear power development. The PGDP historic district encompasses the area of the process buildings; the switchyards; the C-100 Administration Building; cooling towers and pump houses; security facilities; water treatment facilities; storage tanks; and the support, maintenance, and warehouse buildings. A map and the rationale for designating the area as such are included in the Cultural Resources Management Plan.

2.5.6 Asbestos Program

Numerous facilities at the Paducah Site contain asbestos materials. Compliance programs for asbestos management include identification of asbestos materials, monitoring, abatement, and disposal. Procedures and program plans are maintained that delineate scope, roles, and responsibilities for maintaining compliance with EPA, Occupational Safety and Health Administration, and Kentucky regulatory requirements, as applicable.

2.5.7 Solid Waste Management

The Paducah Site disposes of a portion of its solid waste at its contained landfill facility, C-746-U Solid Waste Contained Landfill, under Solid Waste Permit, SW07300045. Construction of the first 5 cells (units) of the C-746-U Landfill began in 1995 and was completed in 1996. The operation permit was received from KDWM in November 1996, which allows for 23 cells. Disposal of waste at the landfill began in February 1997. Operating and groundwater reports for the C-746-U Landfill are submitted quarterly to KDWM. The C-746-U Landfill is permitted to accept for disposal all nonhazardous solid waste including residential, commercial, institutional, industrial, and municipal waste; shredded tires; and nonhazardous spill cleanup residue generated at the Paducah Site. In 2018, only industrial waste was disposed of in the C-746-U Landfill.

DOE placed approximately 1,077 tons of solid waste into the C-746-U Landfill using the C-746-U Authorized Limits. The C-746-U Landfill waste acceptance criteria includes established volumetric and surficial Authorized Limits that govern disposal. Authorized Limits for the C-746-U Landfill initially were established in 2003 and have been maintained since that time. The latest revision was approved by DOE in 2011. Waste streams disposed of within the C-746-U Landfill during CY 2018 include building demolition debris. Table 2.4 provides a summary of Authorized Limit disposal at the C-746-U Landfill during CY 2018 and the cumulative totals since Authorized Limit disposal began in May 2003.

Table 2.4. C-746-U Landfill Authorized Limit Disposal

Cumulative Activity from 2018 Disposal			Total Activity from Disposal 5/21/03 to 12/31/18		
Isotope	**Activity (Curies)**		**Activity (Curies)**	**Source Term Limit (Curies)**	**Percent Utilized***
Americium-241	1.2E-04		7.8E-03	79	0.01%
Cesium-137	3.0E-05		1.1E-02	43	0.03%
Neptunium-237	8.0E-05		1.2E-02	12	0.10%
Plutonium-238	2.0E-05		2.0E-03	88	0.00%
Plutonium-239/240	3.0E-04		1.8E-02	162	0.01%
Technetium-99	9.8E-03		1.1E+00	117	0.99%
Thorium-228	1.0E-04		7.1E-02	9	0.80%
Thorium-230	1.8E-03		2.3E-01	230	0.10%
Thorium-232	1.0E-04		7.1E-02	9	0.80%
Uranium-234	4.7E-03		3.6E-01	360	0.10%
Uranium-235	2.6E-04		1.7E-02	15	0.12%
Uranium-238	8.1E-03		4.1E-01	360	0.11%
					Total % 3.17%

Waste streams added (2018)	1	Waste streams disposed of (2003–2018)	294
Mass disposed of (2018)	2 tons	Mass disposed of (2003–2018)	126,135 tons
		Volume of current cells	386,169 yd^3
		Remaining cell volume	46,174 yd^3

*Percent utilized is the percentage of total activity disposed of divided by the disposal inventory limit, per isotope.

2.6 DEPARTMENTAL SUSTAINABILITY; FEDERAL LEADERSHIP IN ENVIRONMENTAL, ENERGY, AND ECONOMIC PERFORMANCE

2.6.1 Departmental Sustainability

DOE Order 436.1, *Departmental Sustainability*, was enacted May 2, 2011. The Paducah Site currently has no buildings that meet the Guiding Principles of High Performance and Sustainable Buildings. No large renovation projects are viable at this time for buildings at the Paducah Site, but the site continues to implement small upgrades as opportunities present themselves through maintenance replacements such as heating, ventilation, and air conditioning units, etc.

2.6.2 Federal Leadership in Environmental, Energy, and Economic Performance

On May 17, 2018, the President signed Executive Order 13834, *Efficient Federal Operations*. Executive Order 13834 requires that federal agencies meet energy and environmental performance statutory requirements in a manner that increases efficiency, optimizes performance, eliminates unnecessary use of resources, and protects the environment. In support of DOE's goals to meet requirements of Executive Order 13834, DOE submitted a Site Sustainability Plan report identifying the site's progress towards goals through fiscal year (FY) 2018 in December 2018 (SST 2018). Details of the objectives of the Site Sustainability Plan are outlined in Chapter 3 of this report.

2.7 EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW ACT AND TITLE III OF THE SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT

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

hazardous chemical inventories, and releases to the environment, including greenhouse gases. The Paducah Site, as a federal facility, is subject to these reporting requirements.

EPCRA's primary purpose is to increase the public's knowledge and access to information of chemical hazards in their communities. In order to ensure proper and immediate responses to potential chemical hazards, EPCRA Section 302-304 requires facilities to notify state emergency response commissions and local emergency planning committees of inventories and releases of hazardous substances and extremely hazardous substances, when the inventory or release equals or exceeds the reportable quantity. EPCRA Section 302-303 requires notifications to the state and local agencies within 60 days of when a substance on the list of extremely hazardous substances first becomes present at the facility in excess of the respective established threshold planning quantity. Notifications also are required if there is a revision to the list that results in the facility exceeding the revised threshold planning quantity or if there are changes at the facility relevant to emergency planning. These notifications are required within 60 days and 30 days, respectively, of the facility becoming subject to the requirements. The Paducah Site did not receive any such shipments, have production amounts, or make changes at the facility relevant to emergency planning that triggered Section 302-303 reporting for 2018. EPCRA Section 304 requires immediate notification of releases. The Paducah Site did not have any releases equal to or above the minimum reportable quantities; therefore, Section 304 reporting was not required for 2018.

Sections 311 and 312 of EPCRA require businesses to report the safety data sheet, locations, and quantities of chemicals stored on-site to state and local governments in order to help communities prepare to respond to chemical spills and similar emergencies (when chemicals exceed a 10,000 pound reporting threshold). EPCRA Section 311 requires a one-time submittal of safety data sheets of hazardous chemicals present on-site at or above the reporting threshold. In 2018, no EPCRA Section 311 notifications were sent since no new chemicals triggered reporting at the Paducah Site in 2018. EPCRA Section 312 requires notification of the locations and quantities of the subject chemicals. The chemicals stored by all DOE contractors in 2018 (including FRNP, MCS, and SST) were included in an EPCRA 312 Report. The chemicals reported were activated carbon, aluminum oxide, aluminum sulfate, Beet Heet© Concentrate, diesel fuel, calcium oxide, carbon dioxide, chlorine, chlorine trifluoride, cryogenic and gaseous nitrogen, dichlorotetrafluoroethane (R-114), ferric sulfate, ferrous sulfate, fluorine, fuel oil (No. 2), gasoline, hydrofluoric acid, lead acid batteries, nitric acid, oil, potassium hydroxide, propylene glycol, rock salt, sodium carbonate, sodium fluoride, sodium thiosulfate, sulfuric acid (nonbattery), uranium hexafluoride (UF_6), and uranium oxide. [UF_6 was reported as a courtesy, because radioactive substances are not subject to EPCRA Sections 311 and 312 (52 *FR* 38344-01).]

EPCRA Section 313 requires EPA and the states to collect data annually on releases and transfers of certain toxic chemicals from industrial facilities and make the data available to the public.

The site submitted 313 Reports for hydrofluoric acid and chlorine for 2018. Table 2.5 summarizes the EPCRA reporting status for the Paducah Site for 2018.

Table 2.5. Status of EPCRA Reporting

EPCRA Section	Description of Reporting	Status*
EPCRA Sec. 302–303	Planning Notification	Not Required
EPCRA Sec. 304	Extremely Hazardous Substance Release Notification	Not Required
EPCRA Sec. 311–312	Material Safety Data Sheet/Chemical Inventory	Yes
EPCRA Sec. 313	Toxic Release Inventory Reporting	Yes

*An entry of "yes," "no," or "not required" is sufficient for "Status."

2.8 OTHER MAJOR ENVIRONMENTAL ISSUES AND ACTIONS

2.8.1 Green and Sustainable Remediation

Green and sustainable remediation is the practice of using sustainable methods to reduce environmental and social impacts of remedial cleanup and closure activities in a cost effective way. Green and sustainable remediation also offers opportunities to meet compliance obligations at lower overall cost and environmental impact. At the Paducah Site, environmental aspects including, but not limited to, energy use, water use, waste management, air pollution, and reuse of resources are evaluated when planning remediation activities.

2.9 CONTINUOUS RELEASE REPORTING

Section 103(a) of CERCLA requires that hazardous substance releases in excess of a reportable quantity be reported immediately to the National Response Center. Section 103(f)(2) provides relief from the Section 03(a) reporting requirement for hazardous substance releases that are continuous, stable in quantity and rate, and already have been reported. For such releases, notice must be given annually or at such time there is any statistically significant increase in the quantity of hazardous substance released. Releases of this nature typically are included in the Superfund Amendments and Reauthorization Act Title III reports and notifications listed in Section 2.7. There were no continuous releases in 2018.

2.10 UNPLANNED RELEASES

There were two unplanned releases above reportable quantities in 2018. On January 10, 2018, 2,500 gal of oil leaked from the out-of-service electrical equipment located at the C-533 Switchyard. As an immediate response, the leaks from the equipment were isolated, the drainage line exiting the switchyard was sandbagged and plugged, oil was skimmed from the affected waterway, and the remaining oil in the leaking equipment was drained to mitigate any further releases. The efforts proved effective because no oil was released beyond the DOE Site boundary. The leak was suspected to be cold-weather related. Under an expedited settlement agreement with EPA, FRNP paid an assessed penalty of $4,500 in response to the spilled oil. As documented in the expedited settlement agreement, no further clean-up actions were required for the unplanned release.

As a follow-up to the oil spill event, EPA inspected the DOE Paducah Site on January 26, 2018, to determine compliance with 40 *CFR* 112. FRNP received a letter of deficiency from EPA on February 12, 2018 citing certain deficiencies with the facility's Spill Prevention, Control, and Countermeasures (SPCC) Plan. As a result of the notice of deficiency, FRNP completed a revision to the SPCC Plan to address the cited deficiencies. The revised SPCC Plan was submitted to EPA on April 4, 2018, and EPA accepted the revision without comment.

The second unplanned reportable release occurred on February 15, 2018. Approximately 3 lb of asbestos from the thermal system insulation on the overhead steamline was discovered east of facility C-720-G. This release of asbestos exceeded the CERCLA reportable quantity limit of 1 lb for friable asbestos. The spilled asbestos was removed and disposed of in a compliant manner.

Another release occurred in 2018 that was not above a reportable quantity. On January 2, 2018, less than 1 lb of hydrogen fluoride leaked from a piece of pipe that was being removed from the C-400 Cleaning Building. Subsequently, the section of pipe was taped on both ends and put into a bag; the bag then was sealed and was disposed of properly.

2.11 SUMMARY OF PERMITS

Table 2.6 provides a summary of the Paducah Site environmental permits maintained by DOE in CY 2018.

Table 2.6. Permits Maintained by DOE for the Paducah Site for CY 2018

Permit Type	Issued By	Permit Number	Issued To
State Agency Interest ID No. 3059			
Clean Water Act			
Kentucky Pollutant Discharge Elimination System	KDOW	KY0004049	DOE/FRNP/MCS
Permit to Withdraw Public Water	KDOW	0900	FRNP
Water Treatment Registration	KDOW	Public Water System KY0732457	FRNP
Clean Air Act			
Conditional Major Operating Air Permit	KDAQ	F-15-042 R1	MCS
Title V Air Permit	KDAQ	V-14-012 R3	FRNP
RCRA—Solid Waste			
Residential Landfill (closed)	KDWM	SW07300014	DOE/FRNP
Inert Landfill (closed)	KDWM	SW07300015	DOE/FRNP
Solid Waste Contained Landfill (construction/operation)	KDWM	SW07300045	DOE/FRNP
RCRA—Hazardous Waste			
Hazardous Waste Facility Permit	KDWM	KY8-890-008-982	DOE/FRNP
Hazardous and Solid Waste Amendments Portion of the RCRA Permit	EPA	KY8-890-008-982	DOE/FRNP

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3. ENVIRONMENTAL MANAGEMENT SYSTEM

The EMS is designed to integrate environmental protection, environmental compliance, pollution prevention, and continual improvement into work planning and execution throughout all work areas. The Paducah Site implements sound stewardship practices in the protection of land, air, water, and other natural or cultural resources potentially impacted by site operations. The objectives are integrated into the Integrated Safety Management System established by the DOE Policy 450.4A, *Safety Management System Policy*.

Environmental protection programs at the Paducah Site conform to the six core elements of the International Organization for Standardization Environmental Management System ISO 14001:2015 standard through self-declaration. The major elements of an effective System include leadership, planning, support, operation, performance evaluation, and improvement. Through implementation of the EMS, effective protection to workers, the surrounding communities, and the environment can be achieved while meeting operating objectives that comply with legal and other requirements. Feedback information is analyzed to determine the status of the program relative to implementation, integration, and effectiveness.

DOE Contractor's Environmental Policy Statements emphasize conservation and protection of environmental resources by incorporating pollution prevention and environmental protection into the daily conduct of business. The DOE contractors implemented this policy through the programs described in this document, environmental cleanup, pollution prevention programs, and by integrating environmental protection, environmental regulatory compliance, and continual improvement into the daily planning and performance of work at the Paducah Site. The environmental policies are communicated to employees through various methods. The DOE contractor program manager reviews and communicates the commitments in the policy with all of the other members of the DOE contractor management team. The policy is communicated to employees and to subcontractors through sitewide communication, EMS awareness training, and publications.

The EMS environmental stewardship scorecard assesses agency performance in environmentally preferable purchasing; environmental management system implementation; electronics stewardship; high performance sustainable buildings; and environmental compliance management improvement. The EMS environmental stewardship scorecard for the Paducah Site in FY 2018 was green (which indicates standards for EMS implementation have been met).

3.1 ENVIRONMENTAL OPERATING EXPERIENCE AND PERFORMANCE MEASUREMENT

DOE and its contractors are committed to enhancing environmental stewardship and to reducing any impacts that site operations may cause to the environment. The Environmental Monitoring Program at the Paducah Site consists of effluent monitoring, environmental surveillance, and air monitoring around the plant. Requirements for routine environmental monitoring programs were established to measure and monitor effluents from DOE operations and maintain surveillance on the effects of those operations on the environment and public health through measurement, monitoring, and calculation. FRNP implements the Environmental Monitoring Program for the Paducah Site documented in the Environmental Monitoring Plan (FRNP 2018a).

In addition to environmental monitoring documented in the Environmental Monitoring Plan, MCS also monitors radionuclide air emissions as required by their air permit. The results of these programs are discussed in detail in subsequent chapters of this report.

3.1.1 Site Sustainability Plan

In accordance with DOE Order 436.1 and Executive Order 13834, this report provides information concerning the requirements and responsibilities of managing sustainability on the Paducah Site including (1) to ensure DOE carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges, while advancing sustainable, reliable and efficient energy for the future; (2) to initiate wholesale cultural change to factor sustainability and greenhouse gas reductions into all of DOE's corporate management decisions; and (3) to ensure that DOE achieves the sustainability goals established in its Site Sustainability Plan pursuant to any applicable laws, regulations, executive orders, sustainability initiatives, and related performance scorecards.

Table 3.1 is adapted from the Paducah Site FY 2019 Site Sustainability Plan from the web-based DOE Sustainability Dashboard. Site sustainability plans now are organized by overarching categories, rather than by goals, to reduce redundancies and streamline reporting.

When enrichment operations at the Paducah Site ended in FY 2014 and previously leased facilities were returned to DOE, the Environmental Management footprint went from 722,390 gross square footage to 8,174,722 gross square footage. With the return of the previously leased facilities, the site incurred significant increases in utility consumption compared to its baseline values established in FY 2008, which skew attainment of planned goals.

Table 3.1. DOE Sustainability Goal Summary Table[4]

DOE Goal	Current Performance Status	Performance & Plans
Multiple Categories		
Reduce direct greenhouse gas emissions by 50% by FY 2025 from an FY 2008 baseline.	Interim Target: -25% Current Performance: 1248.5%	With return of leased facilities from a private entity to the government, the government increased utility consumption. Facilities not part of the FY 2008 baseline now are part of the Environmental Management mission at the Paducah Site. Reductions in utility usage are anticipated with utility optimization projects, space consolidation, and reductions to site footprint.
Reduce greenhouse gas emissions from sources not owned/directly controlled by the Paducah Site by 25% by FY 2025 from an FY 2008 baseline.	Interim Target: -9% Current Performance: 93.7%	Site contractors will continue a consolidated, four day, 10-hour work schedule. These events will reduce greenhouse gas emissions from sources not owned/directly controlled by the Paducah Site (i.e., personal vehicles).

[4] The Paducah Site has one goal that is not listed on this 2018 DOE Sustainability Goal Summary Table. The goal to transfer 500 acres of real property to the public is not listed, but it is documented in FRNP-RPT-0014/R1, *Strategic Plan for Real Property Transfer at the Paducah Site, Paducah, Kentucky*, Date Issued—April 2018.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
Energy Management		
Reduce energy intensity by 25% by FY 2025 from an FY 2015 baseline.	Interim Target: -5% Current Performance: -70.4%	The Paducah Site identified 33 small structures for demolition in FY 2019.
Section 432 continuous (4-year cycle) energy and water evaluations.	An American Society of Heating, Refrigerating and Air-Conditioning Engineers Level I audit report of 25% of Deactivation and Remediation facilities was finalized in November 2016.	The Paducah Site will use the condition asset surveys with supplemental energy and water checks to meet the EISA 432 energy and water evaluations.
Meter all individual buildings for electricity, natural gas, steam, and water where cost-effective and appropriate.	The Paducah facilities are typically older and do not have individually installed water, electrical, or gas meters. Existing meters are maintained, as appropriate.	Water meters will be installed at C-100 and C-103. Gas and electric meters also will be installed at C-100. The new C-104 and C-208 facilities will have electric and gas meters installed.
Water Management		
36% potable water intensity (gal per gross ft^2) reduction by FY 2025 from an FY 2007 baseline.	Interim Target: -20% Current Performance: 431.5%	There was a 16.3% reduction in potable water usage from FY 2015 to FY 2018.
30% water consumption (gal) reduction of industrial, landscaping, and agricultural water by FY 2025 from an FY 2010 baseline.	Interim Target: -14% Current Performance: 0%	The Paducah Site has no metered industrial, landscaping, and agricultural water.
Waste Management		
Divert at least 50% of nonhazardous solid waste, excluding construction and demolition debris.	Interim Target: 50% Current Performance: 43.2%	The Paducah Site plans to continue meeting at least 50% diversion of nonhazardous solid waste.
Divert at least 50% of construction and demolition materials and debris.	Interim Target: 50% Current Performance: 78.8%	If new construction is performed, the site will attempt to meet the goal to divert at least 50% of waste materials and debris. Due to the radiological contamination at the Paducah Site, recycling of demolition debris is not always feasible. Demolition debris will be evaluated for recycling on a case by case basis, as appropriate.
Fleet Management		
30% reduction in fleet-wide per-mile greenhouse gas emissions reduction by FY 2025 from an FY 2014 baseline.	Interim Target: -4% Current Performance: -17.8%	All Site contractors continue to evaluate the number and type of fleet vehicles required. During the first quarter of FY 2018, the current Deactivation and Remediation Contractor initiated a 13.5% overall reduction in fleet leased vehicles.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
20% reduction in annual petroleum consumption by FY 2015 relative to an FY 2005 baseline; maintain 20% reduction thereafter.	Interim Target: -20% Current Performance: 2397.3%	Plant personnel are encouraged to utilize Alternative Fuel Vehicles (AFVs) and the contractors are promoting E-85 use within plant communication mediums.
10% increase in annual alternative fuel consumption by FY 2015 relative to an FY 2005 baseline; maintain 10% increase thereafter.	Interim Target: 10% Current Performance: 41%	Communication tools are and will continue to be utilized to encourage the use of alternative fuel. Opportunities to increase E85 usage will continue to be tracked and reviewed on a monthly basis.
75% of light-duty vehicle acquisitions must consist of alternative fuel vehicles.	Deactivation and Remediation = 0% SST = 0% MCS = 0%	Majority of site passenger vehicles consist of AFVs. In FY 2018, 99% of General Services Administration fleet was leased, and replacement-eligible vehicles were replaced with AFVs.
50% of passenger vehicle acquisitions consist of zero emission or plug-in hybrid electric vehicles by FY 2025.	No vehicles on-site meet criteria, at this time.	Site fleet currently does not utilize zero emission/plug-in hybrid vehicles due to lack of infrastructure to support charging.
Clean & Renewable Energy		
"Clean Energy" requires that the percentage of an agency's total electric and thermal energy accounted for by renewable and alternative energy shall be not less than 25% by FY 2025 and each year thereafter.	Interim Target: 10% Current Performance: 0%	Currently, the site has no on-site renewable energy generation capability.
"Renewable Electric Energy" requires that renewable electric energy account for not less than 30% of a total agency electric consumption by FY 2025 and each year thereafter.	Interim Target: 10% Current Performance: 0%	Currently, the site has no on-site renewable energy generation capability.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
Green Buildings		
At least 17% (by building count) of existing buildings greater than 5,000 gross ft^2 to be compliant with the revised Guiding Principles for High Performance Sustainable Buildings by FY 2025, with progress to 100% thereafter.	Interim Target: 15% Current Performance: 0%	No existing buildings meet the Guiding Principles, nor is it economically feasible because all buildings are scheduled for decontamination and decommissioning.
Net Zero Buildings: 1% of the site's existing buildings above 5,000 gross ft^2 intended to be energy, waste, or water net-zero buildings by FY 2025.	No facilities at Paducah presently meet the criteria.	Because activities at the site are focused on ultimately demolishing existing > 5,000 gross square foot buildings, these buildings may qualify as Net Zero when they are isolated from all site utilities prior to demolition.
Net Zero Buildings: All new buildings (> 5,000 gross ft^2) entering the planning process designed to achieve energy net-zero beginning in FY 2020.	No facilities at Paducah presently meet the criteria.	At this time, there are no plans related to this goal.
Increase regional and local planning coordination and involvement.	The Paducah Site has no projects planned that fit the requirements.	The Paducah Site currently is in deactivation. The Citizens Advisory Board will continue as chartered.
Acquisition and Procurement		
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring bio-preferred and bio-based provisions and clauses are included in 95% of applicable contracts.	Interim Target: 95% Current Performance: 2400%	Applicable contracts contain sustainable acquisition clauses.
Measures, Funding, and Training		
Annual targets for performance contracting to be implemented in FY 2017 and annually thereafter as part of the planning of Section 14 of Executive Order 13693.	DOE is using the DOE energy conservation program to construct the new DOE-Tennessee Valley Authority substation.	Design of the new Tennessee Valley Authority/DOE substation will continue with an anticipated completion date in FY 2020.
Electronic Stewardship		
Purchases—95% of eligible acquisitions each year are Electronic Product Environmental Assessment Tool-registered products.	Interim Target: 95% Current Performance: 83.3%	All products purchased in FY 2018 were Electronic Product Environmental Assessment Tool-registered products, except for 3 televisions.

Table 3.1. DOE Sustainability Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
Power management—100% of eligible PCs, laptops, and monitors have power management enabled.	Interim Target: 100% Current Performance: 100%	Power management is actively implemented on all eligible computers.
Automatic duplexing—100% of eligible computers and imaging equipment have automatic duplexing enabled.	Interim Target: 100% Current Performance: 100%	All eligible computers and printers have duplexing capabilities.
End of Life—100% of used electronics are reused or recycled using environmentally sound disposition options each year.	Interim Target: 100% Current Performance: 100%	During FY 2018, there was an electronic-scrap shipment of 14,300 lb to a recycler.
Data Center Efficiency. Establish a power usage effectiveness target in the range of 1.2–1.4 for new data centers and less than 1.5 for existing data centers.	1.5 Power Usage Effectiveness	Will review server and power infrastructure and pursue options to improve efficiency by replacement of older equipment and continuing efforts to virtualize the server environment.
Organizational Resilience		
Discuss overall integration of climate resilience in emergency response, workforce, and operations procedures and protocols.		Paducah has no specific actions for climate change resilience. Site emergency response agreements do not account specifically for climate change protocols; however, they do address weather-related concerns.

3.1.2 Waste Minimization/Pollution Prevention

The Waste Minimization/Pollution Prevention Program at the Paducah Site provides guidance and objectives for minimizing waste generation. The program is set up to comply with RCRA and the Pollution Prevention Act, as well as applicable Commonwealth of Kentucky and EPA rules, DOE Orders, executive orders, and the Site Treatment Plan. All of the Paducah Site projects are evaluated for waste minimization/pollution prevention opportunities. Materials recycled included oils, paper, toner cartridges, scrap metal (nonradiological), aluminum cans, light bulbs, batteries, tires, plastics, cardboard, and over seven tons of used electronics.

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

The program has the following goals and objectives:

- Eliminate or reduce the amount and toxicity of all waste generated at the site;
- Comply with federal and state regulations and DOE requirements for waste minimization;
- Reuse or recycle materials when possible;
- Identify waste reduction opportunities;
- Integrate waste minimization/pollution prevention technologies into ongoing projects;
- Coordinate recycling programs; and
- Track and report results.

Waste minimization/pollution prevention efforts for the site are reported in DOE's Sustainability Dashboard. As part of waste minimization/pollution prevention efforts at the Paducah Site, the Infrastructure Contractor offers excess reusable items to Paducah Area Community Reuse Organization. During CY 2018, the Paducah Site diverted 43.21% of its waste from disposal in municipal landfills, including paper, scrap metal, wood pallets, batteries, cardboard, plastic, and electronic items.

Waste minimization/pollution prevention accomplishments at the Paducah Site related to the Site Treatment Plan waste minimization/pollution prevention in CY 2018 were the following (DOE 2019a). This list does not represent all recycling efforts made at the Paducah Site and is only the potential hazardous waste that was diverted.

- Regenerated 21,820 pounds of activated carbon averting disposal;
- Recycled 8,210 pounds of scrap metal;
- Returned 3,300 pounds of fluorine to the vendor for reprocessing;
- Recycled 4,144 pounds of various light bulbs; and
- Recycled 41,931 pounds of various batteries.

3.1.3 Depleted Uranium Hexafluoride Cylinder Program

A byproduct of the uranium enrichment process, DUF_6 is a solid at ambient temperatures and is stored in large metal cylinders. At the end of 2018, the Paducah Site managed an inventory of approximately 51,600 cylinders stored in cylinder storage yards.

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

The DUF_6 facility converts the inventory of DUF_6 to triuranium octaoxide (U_3O_8), a more stable form of uranium, and hydrofluoric acid sold for commercial use. During 2018, MCS converted approximately 5,366 metric tons of DUF_6 to a more stable oxide and hydrofluoric acid. Off-site shipment is discussed in Section 4.2.

3.1.4 Environmental Restoration

The environmental restoration program supports investigations and environmental response actions, deactivation and decommissioning of facilities, projects designed to demonstrate or test advancements in remedial technologies, and other projects related to action for the protection of human health and the environment.

The following are Paducah Site significant accomplishments in 2018.

- Received federal and state regulatory approval of the *Remedial Action Completion Report for the Interim Remedial Action for the Groundwater Operable Unit for the Volatile Organic Compound Contamination at the C-400 Cleaning Building at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2417&D2 (DOE 2018b).

- Received federal and state regulatory approval of the *Postconstruction Report for the Northeast Plume Optimization at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2419&D2/R1 (DOE 2018c).

- Received federal and state regulatory approval of the *Remedial Investigation/Feasibility Study Report for CERCLA Waste Disposal Alternatives Evaluation at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-0244&D2/R2 (DOE 2018d).

- Received federal and state regulatory approval of the *Feasibility Study for Solid Waste Management Unit 4 of the Burial Grounds Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2408&D2/R1 (DOE 2018e).

- Completed the C-400 Vapor Intrusion Study and received regulator concurrence on the *C-400 Vapor Intrusion Study Addendum to the 2013 Five-Year Review for Remedial Actions at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-1289&D2/Rl/A3/Rl (DOE 2018f).

- Submitted the *Removal Notification for Demolition of the C-400 Cleaning Building in the C-400 Complex Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2420&D2 (DOE 2018g).

- Submitted the *Engineering Evaluation/Cost Analysis for Demolition of the C-400 Cleaning Building in the C-400 Complex Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2425&D2 (DOE 2018h).

- Submitted the *Action Memorandum for the C-400 Cleaning Building Non-Time-Critical Removal Action at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2427&D1 (DOE 2018i).

- Submitted the *Removal Action Work Plan for Demolition of the C-400 Cleaning Building in the C-400 Complex Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2432&D1 (DOE 2018j).

- Submitted the *Remedial Investigation/Feasibility Study Work Plan for the C-400 Complex Operable Unit at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2433&D1 (DOE 2018k).

- Received federal and state regulatory approval of the *Community Relations Plan under the Federal Facility Agreement at the U.S. Department of Energy Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2413&D2 (DOE 2018l).

3.1.5 Emergency Management

Emergency management planning is a systematic, integrated effort at the Paducah Site in the rare event that site activities could impact site workers or the public. Members of the Paducah Site Emergency Response Organization include the Crisis Manager and the Emergency Operations Center cadre, an Incident Commander, and the Emergency Squad. In the event of an emergency, the Joint Public Information Center provides timely and accurate information to the community.

The Paducah Site also maintains a fully staffed fire department along with protective force officers and a medical facility. DOE's various contractors have separate emergency response procedures that they practice during training exercises to bolster their ability to work together.

3.1.6 Facility Stabilization, Deactivation, and Infrastructure Optimization

Stabilization and deactivation projects at the Paducah Site involve isolating utilities, removal and compliant disposition of hazardous materials from facilities, and downgrading radiological facilities to make ready for demolition. The following are significant Paducah Site accomplishments in 2018.

Figure 3.1. DOE and its Contractors Work with School Students as a Part of its Community Outreach Efforts

- Continued deactivation of C-400 Cleaning Building, to include removal of fire loading in order to deactivate the fire system, criticality accident alarm system (CAAS) isolation, ventilation system isolation, and drain pipe isolation.
- Initiated C-360 Toll, Transfer and Sampling Building deactivation by isolating the CAAS and fire systems in order to support future demolition.
- Deactivation of electrical switchyards including draining of all electrical components which resulted in the recovery and recycling of approximately 500,000 gal of dielectric fluid.
- Returned 3,300 lb of fluorine to the vendor for reprocessing. This effort brought the site below the EPA reporting requirement for fluorine as a regulated toxic substance.
- Removed 17 aging and deteriorating small structures which included office support trailers.

3.2 ACCOMPLISHMENTS, AWARDS, AND RECOGNITION

DOE and its contractors are committed to enhancing public awareness and community/educational outreach. The Paducah Citizens Advisory Board and the DOE Environmental Information Center are both avenues through which DOE interacts with the public. In addition to public outreach, DOE's contractors have received recognition for their work.

3.2.1 Public Awareness Program

A comprehensive Community Relations Plan exists for DOE activities at the Paducah Site (DOE 2018l).

DOE continued conducting guided public tours of its Paducah Site in 2018. Ten tours were conducted in 2018, totaling approximately 400 participants, for the public to learn about the history of PGDP.

3.2.2 Community/Educational Outreach

DOE supported several educational and community outreach activities during 2018 (Figure 3.1). Site employees participated in a "Feds Feed Families" program in which employees brought nonperishable food items to donate to local food pantries.

DOE and its contractors engaged students through educational outreach programs such as the annual DOE National Science Bowl, for which regional competitions were held in February for Western Kentucky and Southern Illinois middle and high schools. DOE and its contractors also supported the Western Kentucky Regional Science Fair, local school career fairs, and a middle school Science, Technology, Engineering, and Math program (Figure 3.2). In 2018, students from the Marshall County School district visited the Paducah Site for development of the ASER summary.

Figure 3.2. STEM 4 Girls Event

The Kentucky Research Consortium for Energy and Environment continued development of the "Virtual Museum for the Paducah Site." This Web resource maintains an archive of information that can be used to communicate to stakeholders, especially the public, the history, local impact, and cleanup of the Paducah Site. As part of this development, the Kentucky Research Consortium for Energy and Environment worked with the site to develop content. Additional information is available at the following link: http://www.ukrcee.org/.

In 2018, DOE sponsored a 10-week Internship Program for college students to work and be mentored by engineers, project managers, and leaders in the business, safety, and regulatory departments to get a first-hand, realistic perspective of what they would like to do after graduation (Figure 3.3).

Figure 3.3. Intern Participating in Site Surveying

Paducah PPPO Environmental Geographic Analytical Spatial Information System (PEGASIS) is designed to provide dynamic mapping and environmental monitoring data display. The information made available and the environmental data display tools developed for PEGASIS are the result of input from various stakeholders including DOE and contractor staff, regulatory agencies, and members of the public. PEGASIS is continuously being updated to enhance usability and to include new features. Data available in PEGASIS are updated on a quarterly basis. Training sessions for PEGASIS are available by contacting the PEGASIS administrator. See https://pegasis.pad.pppo.gov/what-is-pegasis.html.

3.2.3 Citizens Advisory Board

The Paducah Citizens Advisory Board is a site-specific advisory board chartered by DOE under the Federal Advisory Committees Act. During the CY, the Citizens Advisory Board held several regular board meetings and additional subcommittee meetings.

The Citizens Advisory Board is composed of up to 18 members, representing the general public from western Kentucky and surrounding areas. The Citizens Advisory Board is committed to reflecting the concerns of the communities impacted by environmental management of the plant site. It meets bimonthly to focus on early participation in environmental cleanup priorities and related issues at the DOE facility. Additional information concerning the Citizens Advisory Board may be obtained at https://www.energy.gov/pppo/pgdp-cab/paducah-citizens-advisory-board.

The Paducah Citizens Advisory Board generally works to achieve its mission through its subcommittee structure, and each year the board holds a planning meeting to determine how best to address its mission. An active educational series operating in an administrative and preparatory manner to prepare board members and future subcommittees for the task of advising DOE. The educational series was developed based on future project priorities, as selected by the board members, with guidance from DOE (PGDP CAB 2017). The educational series during the CY consisted of the following:

- Paducah Site Baseline
- C-400 Complex Operable Unit
- Deactivation and Non-destructive Assay

All regular board meetings are open to the public and publicly advertised. In addition to its voting members, the Citizens Advisory Board also has liaison members representing EPA Region 4, Kentucky Cabinet for Health and Family Services, and WKWMA.

3.2.4 Environmental Information Center

The public has access to the electronic version of the Administrative Records and programmatic documents at the Environmental Information Center located at the Emerging Technology Center, Room 221, 5100 Alben Barkley Drive, Paducah, Kentucky. The Environmental Information Center is open Monday through Friday from 8 a.m. to 12 p.m. and by appointment. The Environmental Information Center's phone number is (270) 554-3004.

Documents for public comment also are placed in the McCracken County Public Library, 555 Washington Street, Paducah, Kentucky. The library is open Monday through Thursday from 9 a.m. to 9 p.m., Friday through Saturday from 9 a.m. to 6 p.m., and Sunday from 1 p.m. to 6 p.m.

The Environmental Information Center and other public Web pages related to DOE work at the Paducah Site can be accessed at https://eic.pad.pppo.gov/ and http://energy.gov/pppo/paducah-site.

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4. ENVIRONMENTAL RADIOLOGICAL PROTECTION PROGRAM AND DOSE ASSESSMENT

4.1 ENVIRONMENTAL RADIOLOGICAL MONITORING PROGRAM

Routine DOE operations at the Paducah Site result in releases of radioactive materials to the environment by atmospheric and liquid pathways. These releases potentially result in a radiation exposure to the public. In accordance with DOE Order 458.1, *Radiation Protection of the Public and the Environment*, DOE has an environmental surveillance program that includes radiological monitoring of pathways which may contribute to dose to the public. Surveillance includes analyses of surface water, groundwater, sediment, direct radiation, and ambient air (FRNP 2018a). DOE has established dose limits for the public and biota. The dose limit to the public is 100 millirem (mrem) per year summed over all sources of ionizing radiation and exposure pathways. Doses are to be optimized through the application of ALARA principles so that DOE operations will not contribute significantly to the average annual exposure. Doses to biota is limited to 1 rad/day (a unit of absorbed dose) for protection of aquatic organisms, 1 rad/day for protection of terrestrial plants, and 0.1 rad/day for protection of terrestrial animals. To confirm that doses are below public and biota dose limits, the Paducah Site calculates annual dose estimates using effluent release data, environmental monitoring data, and surveillance data combined with relevant site specific data (such as meteorological conditions, population characteristics, and stream flows).

Surface water is not used as a source of public drinking water on the DOE Reservation; however, data from these outfalls are included as part the incidental surface water ingestion pathway. To assess fully the potential dose to the public, a hypothetical set of characteristics was used to postulate an upper bound exposure scenario.

4.1.1 What Is Dose?

Dose is the amount of energy absorbed by the human body as a result of a radioactive source; it is measured in rem [which equals 0.01 sievert (Sv)] or in mrem, which is one-thousandth of a rem. These exposures/intakes involve the transfer of energy from radiation to tissue and can result in tissue damage. Exposures to radiation from radionuclides outside the body are called external exposures; exposures to radiation from radionuclides inside the body are called internal exposures. This distinction is important because external exposure occurs only as long as a person is near the radionuclide; simply leaving the area of the source will stop the exposure. Internal exposure continues as long as the radionuclide remains inside the body.

Members of the public are routinely exposed to natural and man-made sources of ionizing radiation. An individual living in the U.S. is estimated to receive an average annual effective dose of about 620 mrem (6.2 mSv) (NCRP 2009). Half of the radiation dose to a member of the public, about 310 mrem/year, is from natural background sources of cosmic and terrestrial origin (Figure 4.1). The other half is from man-made sources, including diagnostic and therapeutic X-rays, tomography, and fluoroscopy; nuclear medicine; consumer products, such as cigarettes and smoke detectors; fallout from nuclear weapons tests; industrial, research, and educational applications; and effluents from nuclear facilities.

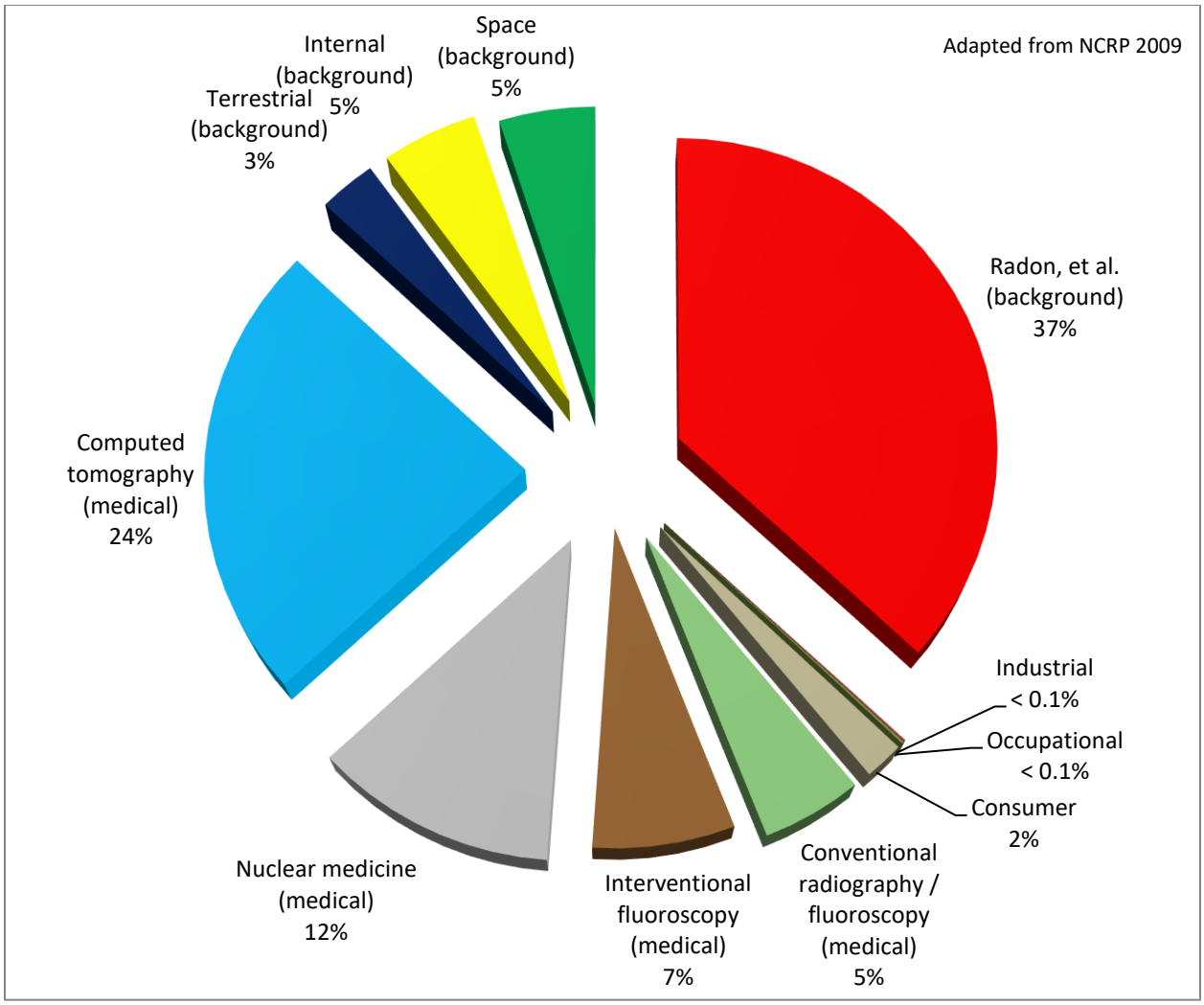

Figure 4.1. Sources of Radiation

Unless otherwise noted, the generic term "dose" used in this report is the total effective dose to a person, which includes both the committed effective dose (50-year committed dose) from internal deposition of radionuclides and the effective dose attributable to sources external to the body. Use of the total effective dose allows doses from different types of radiation and to different parts of the body to be expressed on the same basis. National Council on Radiation Protection and Measurements Report No. 160 noted that the average member of the U.S. population was exposed to significantly more radiation from medical procedures than from any other source. Approximately half of an average individual's dose is attributed to natural sources (radon 37% and 13% is cosmic, terrestrial, and internal). Dose from nuclear power was grouped into a category comprising < 0.1%. The remaining dose was from medical exposures (approximately 48% of the total dose).

DOE has established dose limits to the public so that DOE operations will not contribute significantly to this average annual exposure. DOE Order 458.1 establishes 100 mrem/year above background as the total annual dose limit to a member of the public. The established 100 mrem/year dose limit is consistent with Nuclear Regulatory Commission and Kentucky Radiation Health Branch dose limits for the public. Each year, DOE operations at the Paducah Site contribute to the public dose through radiological releases and direct radiation. Emissions and effluents are controlled so that releases are maintained ALARA. To confirm

that doses to the public and biota are below established limits, the Paducah Site calculates annual dose estimates using effluent release data, direct radiation monitoring data, and environmental monitoring data combined with relevant site specific data (such as meteorological conditions and population characteristics). These dose calculations use various computer codes that model the environmental dispersion of radionuclides that originate from on-site activities.

4.1.2 Radioactive Materials at the Paducah Site

Radioactive materials present at the Paducah Site are the result of processing raw and recycled uranium. The Paducah Site associated radionuclides and their half-lives are listed below:

- Uranium-234 (245,000 year half-life)
- Uranium-235 (704,000,000 year half-life)
- Uranium-238 (4,470,000,000 year half-life)
- Thorium-230 (75,400 year half-life)
- Technetium-99 (211,000 year half-life)
- Plutonium-238 (87.7 year half-life)
- Plutonium-239 (24,100 year half-life)
- Plutonium-240 (6,560 year half-life)
- Neptunium-237 (2,140,000 year half-life)
- Americium-241 (432 year half-life)
- Cesium-137 (30.2 year half-life)

Decay products for the radionuclides listed above also are present at the Paducah Site in minute quantitites. As discussed in Section 4.1.1, members of the public are routinely exposed to natural background and man-made sources of ionizing radiation. The radioactive materials present at the Paducah Site do not contribute significantly to the public's average annual exposure when compared to natural background and man-made sources of radiation.

The monitoring program for radioactivity in liquid and airborne effluents is described fully in the Paducah Site Environmental Monitoring Plan (FRNP 2018a).

4.1.3 What is an Exposure Pathway?

An exposure pathway is how a radioactive material is released to the environment, transported to a receptor (person, animal, or plant), and comes into contact with a receptor (Figure 4.2). Routine operations at the Paducah Site may release incidental radioactive materials into the environment through atmospheric and liquid discharges. The principal routes by which people come into contact with released radioactive material are the following:

- Inhalation of gases and particulates;
- Ingestion of vegetables, crops, wild game, milk, and fish;
- Ingestion of surface water and groundwater;
- Skin absorption (also called dermal absorption); and
- External exposure to ionizing radiation.

4.1.4 Dose Assessment Methodology

Radiological exposure assessments are modeled using exposure pathways applicable to the Paducah Site utilizing methods consistent with the requirements of DOE Order 458.1 and various guidance, including the *Methods for Conducting Risk Assessments and Risk Evaluations* (DOE 2018a). First, measurements (and/or estimates) of radionuclide concentrations in liquid and air released from the Paducah Site are

assembled from the CY of interest. Then EPA- and DOE-approved models, or factors derived from those models, are used to estimate the total effective dose to the maximally exposed individual and the collective total effective dose to the population within a 50-mile radius and estimated background dose (DOE 2011a).

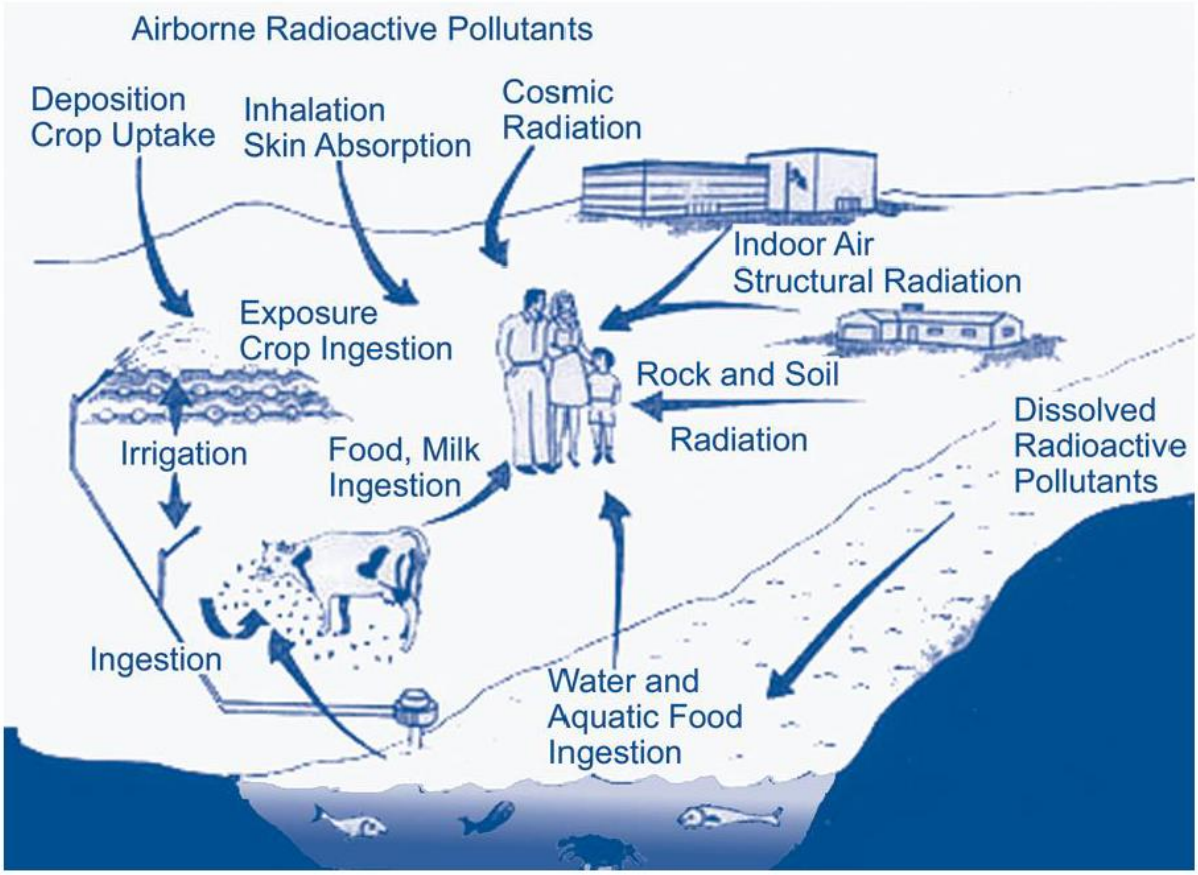

Figure 4.2. Potential Exposure Pathways

The maximally exposed individual is the hypothetical resident who has the greatest probability of being affected by a radiological release.

For determining compliance with the DOE public dose requirements, the Paducah Site calculates the potential off-site doses from the Paducah Site effluent releases of radioactive materials (atmospheric and liquid) for the maximally exposed individual and the population living within a 50-mile radius of the Paducah Site. In accordance with DOE Order 458.1, the pathway and exposure assumptions for the maximally exposed individual are to be reasonable and not underestimate the dose or substantially overestimate the dose. The maximally exposed individual for the Paducah Site is established based on lifestyle assumptions for radiological exposure that would yield an overestimation of dose for a hypothetical individual who lives near the Paducah Site at the location where the highest concentration of radionuclides in air has been modeled; consumes milk, meat, and vegetables produced at that location; spends time on or near Bayou or Little Bayou Creeks; and hunts on the wildlife reservation (DOE 2018a). Dose is expected to be overestimated because certain assumptions (such as swimming in nearby creeks) are not expected. This person does not drink groundwater because all persons potentially impacted by the Paducah Site have access to public water. Surface water for irrigation of crops is assumed to come from an uncontaminated source and not from either Bayou or Little Bayou Creek, which have too little flow for this use in comparison to the Ohio River. Furthermore, Little Bayou Creek does not support aquatic life for

consumption, and few game size fish could be caught from Bayou Creek, except when there is a major influx of fish from the Ohio River during a backwater event. Because of this, dose from fish ingestion is not included. Dose from surface water is calculated assuming ingestion at the nearest public withdrawal location, Cairo, Illinois. Dose from incidental sediment and surface water ingestion is based on assumptions for recreational use of the Bayou and Little Bayou Creeks on the reservation. Dose associated with airborne releases are calculated for the hypothetical maximally exposed individual located at the nearest plant neighbor.

4.1.5 Air Monitoring and Estimated Dose from Airborne Effluents

DOE operations result in airborne releases from various sources including CERCLA remedial actions. Radionuclide sources at the Paducah Site evaluated in 2018 were the following:

- Northwest Plume Groundwater Treatment System;
- Northeast Plume Containment System Treatment Units;
- DUF_6 Conversion Facility;
- Laboratory Hoods;
- Building Exhaust Vents; and
- Fugitive Emissions.

Specific activities that could generate fugitive emissions include transport and disposal of waste, decontamination of contaminated equipment, and most environmental remediation activities. Ambient air monitoring, which monitors fugitive emissions from all Paducah Site operations (including DUF_6 Conversion Facility operations), is conducted using nine continuous air monitors surrounding the Paducah Site reservation. One of these air monitors collects data from a background location. See Figure 4.3 for air sampling locations. Radiological analytes are presented in the FY 2018 and FY 2019 Environmental Monitoring Plans (FRNP 2018a; FRNP 2019c).

Airborne radionuclide emissions are regulated by EPA under the Clean Air Act and its implementing regulations. DOE facilities are subject to 40 *CFR* Part 61, Subpart H, NESHAP, which contains the national emission standards for radionuclides other than radon from DOE facilities. The applicable standard is a maximum of 10 mrem (0.1 mSv) effective dose equivalent to any member of the public in any year.

For radionuclides at the Paducah Site, the effective dose equivalent is assumed to be equivalent to the effective dose.

Airborne radioactive materials released in 2018 from stacks and diffuse sources on the Paducah Site (Table 4.1) were modeled using the EPA-approved Version 4 (2014) of the CAP-88 (Clean Air Act Assessment Package–1988) PC computer program. This air dispersion model estimates effective dose equivalents based on the ingestion, inhalation, air immersion, and ground surface pathways including consumption of vegetables, milk, and meat. Site-specific data for CY 2018 (radionuclide releases in curies per year) were input into the CAP-88 PC program, as were on-site meteorological data.

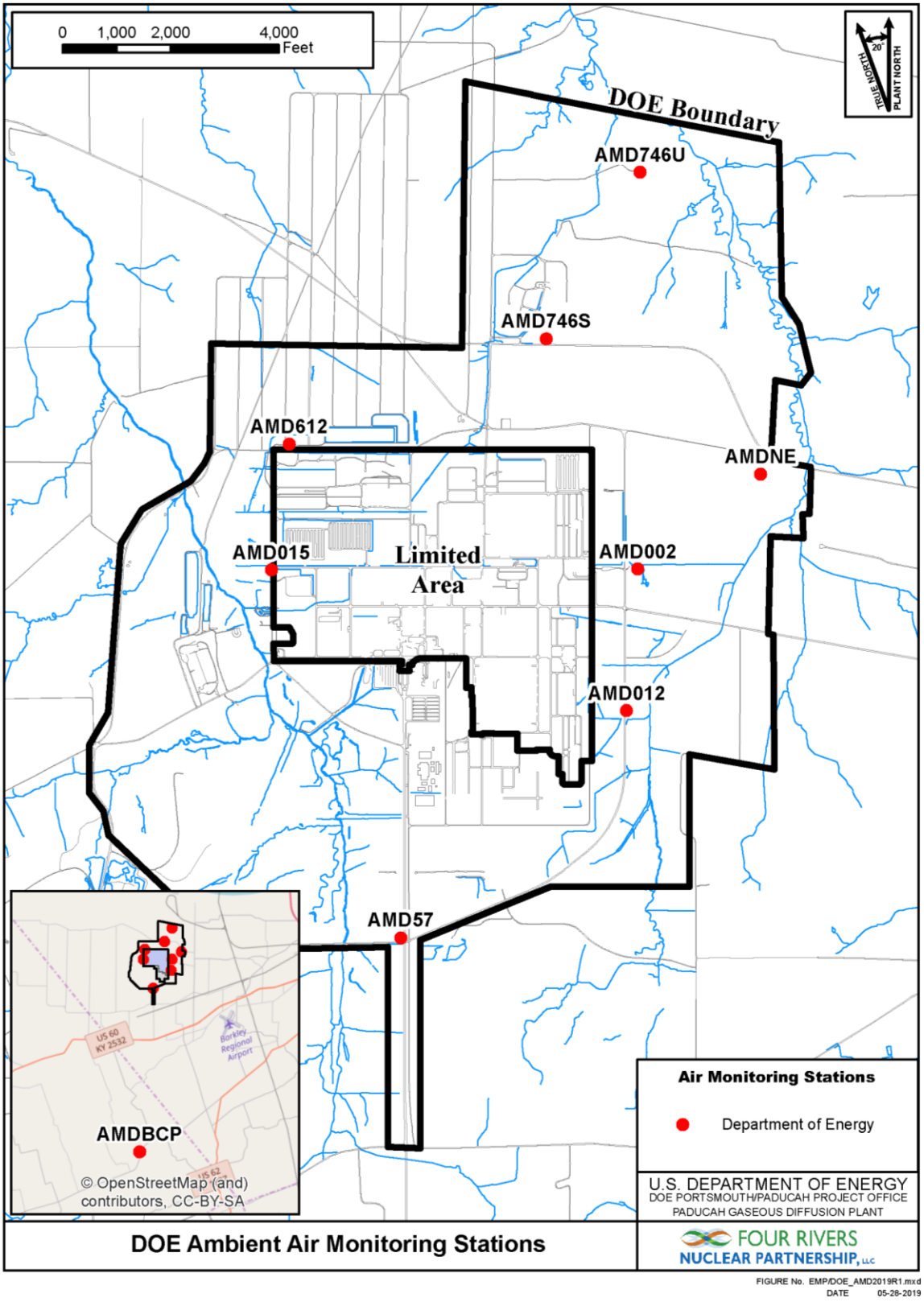

Figure 4.3. Air Monitoring Locations

Table 4.1. Radionuclide Atmospheric Releases for CY 2018 (in Curies) for the Paducah Site*

Radionuclide	Northwest Plume Groundwater Treatment System C-612	Northeast Plume Containment System Treatment Unit C-765	Northeast Plume Containment System Treatment Unit C-765-A	DUF_6 Conversion Facility	Laboratory Hoods	Building Exhaust Vents	Total Site Emissions
Tc-99	9.17E-05	1.24E-05	6.06E-06	0.00E+00	0.00E+00	2.28E-06	1.12E-04
U-234	0.00E+00	0.00E+00	0.00E+00	1.12E-06	1.16E-05	1.37E-05	2.64E-05
U-235	0.00E+00	0.00E+00	0.00E+00	5.11E-08	7.53E-07	7.38E-07	1.54E-06
U-238	0.00E+00	0.00E+00	0.00E+00	2.74E-06	2.63E-05	5.46E-06	3.45E-05
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.22E-09	5.22E-09
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.20E-08	1.20E-08
Th-230	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.22E-08	1.22E-08
Th-231	0.00E+00	0.00E+00	0.00E+00	2.05E-07	0.00E+00	0.00E+00	2.05E-07
Th-234	0.00E+00	0.00E+00	0.00E+00	1.88E-05	0.00E+00	0.00E+00	1.88E-05
Pa-234m	0.00E+00	0.00E+00	0.00E+00	1.88E-05	0.00E+00	0.00E+00	1.88E-05
Total Curies/Year	**9.17E-05**	**1.24E-05**	**6.06E-06**	**4.17E-05**	**3.86E-05**	**2.22E-05**	**2.13E-04**

*Values are taken from *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2018* (FRNP 2019d).

Table 4.1 shows the estimates of radionuclide atmospheric releases in curies (i.e., units of radioactivity), Table 4.2 provides the effective dose to the maximally exposed individual for each individual point source in mrem (i.e., dose of radiation) received in a CY.

Table 4.2. Dose Calculations for Airborne Releases for CY 2018

Emission Sources	Dose to the Maximally Exposed Individual for the Plant (mrem/yr)
Laboratory Hoods	1.80E-05
Building Exhaust Vents	6.50E-06
Northwest Plume Treatment System	6.10E-05
Northeast Plume Treatment Unit C-765	2.40E-06
Northeast Plume Treatment Unit C-765-A	1.10E-06
DUF_6 Conversion Facility	1.20E-06
Total from All Sources	**9.02E-05**

The hypothetical maximally exposed individual was calculated potentially to receive an effective dose equivalent of 0.00009 mrem/yr, which is well below the NESHAP standard of 10 mrem/yr. Based upon 2010 population census data, the collective effective dose to the entire population (534,000 persons) within 50 miles of the Paducah Site is shown in Table 4.3, as estimated by the CAP-88 PC program.

Table 4.3. Calculated Radiation Doses from Airborne Releases for the Paducah Site for CY 2018

Effective Dose to Maximally Exposed Individual (mrem/yr)	Percent of Standard (%)	Collective Effective Dose (person-rem/yr)
9.02E-05	0.0009	6.01E-04

A complete summary of this emissions data can be found in the *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2018* (FRNP 2019d).

4.1.6 Liquid Discharge Monitoring and Estimated Dose from Liquid Effluents

4.1.6.1 Surface water

In general, radioactive contaminants released to surface water may remain dissolved or suspended in surface water, deposited in sediment, deposited on ground or vegetation by irrigation, absorbed into plants and animals, or may infiltrate to the groundwater.

Surface water leaving the Paducah Site includes rainfall runoff from cylinder yards and landfills and effluent from site processes (e.g., the C-612 Northwest Plume Groundwater Treatment System and the C-613 Sedimentation Basin). The discharges from the Paducah Site flow into Bayou and Little Bayou Creeks, which then flow into the Ohio River.

DOE Order 458.1 requires the control and management of radionuclides from DOE activities in liquid discharges and sets guidelines for allowable concentrations of radionuclides in effluents to protect public health. This protection is achieved at the Paducah Site by meeting the limits set in DOE Order 458.1. Ingestion limits for all radionuclides are calculated using the composite DOE-STD-1196-2011, Derived Concentration Technical Standard (DCS) (DOE 2011a). These radiation standards are dose limits, but are not DOE's expectation for dose to the public and the environment. DOE O 458.1 requires application of the ALARA process to all routine radiological activities to reduce radionuclide releases and resulting doses to the extent possible.

Derived concentration technical standard (DCS)—A DOE technical standard that documents the derived concentration value for a radionuclide in water that would result in a dose of 100 mrem in a year to a gender- and age-weighted reference person using DOE-approved dose conversion factors and assuming continuous exposure. The standard is referenced in DOE Order 458.1, *Radiation Protection of the Public and the Environment*.

The ingested water DCS value for a radionuclide is the concentration of the radionuclide in drinking water that is calculated (derived) to result in an annual dose of 100 mrem to a person. That is, if the person's entire annual drinking water intake contained a radionuclide at the DCS level, that person would receive 100 mrem. In reality, people do not intentionally drink any water from surface streams in the area surrounding the Paducah Site; therefore, the allowable concentrations for the DCS result in a dose that is higher than a person would actually receive. The DCS is different for each radionuclide because of the differences in radiation type, radioactive energy, and half-life.

For environmental surveillance monitoring, surface water was sampled quarterly at four locations for radiological parameters (L10, L241, L5, and L11) in 2018 (see Figure 4.4). Background locations (L1 and L29A) are sampled annually; however, these background doses are not subtracted from the site dose. Additionally, a location in the Ohio River immediately downgradient of the plant (L30) was sampled annually and a location near the nearest public water withdrawal location, Cairo, Illinois, (L306) was sampled quarterly. Sampling locations were selected to support site-specific radiation exposure pathway analysis. Locations were prioritized for areas of public access, introduction of plant effluents to the environment, and verification of the effectiveness of the Paducah Site effluent control and monitoring. Areas removed/remediated as part of a 2010 removal action for contaminated sediment associated with the Surface Water Operable Unit are denoted on the figure (DOE 2011b).

There have been no significant surface water trends identified over the past few years.

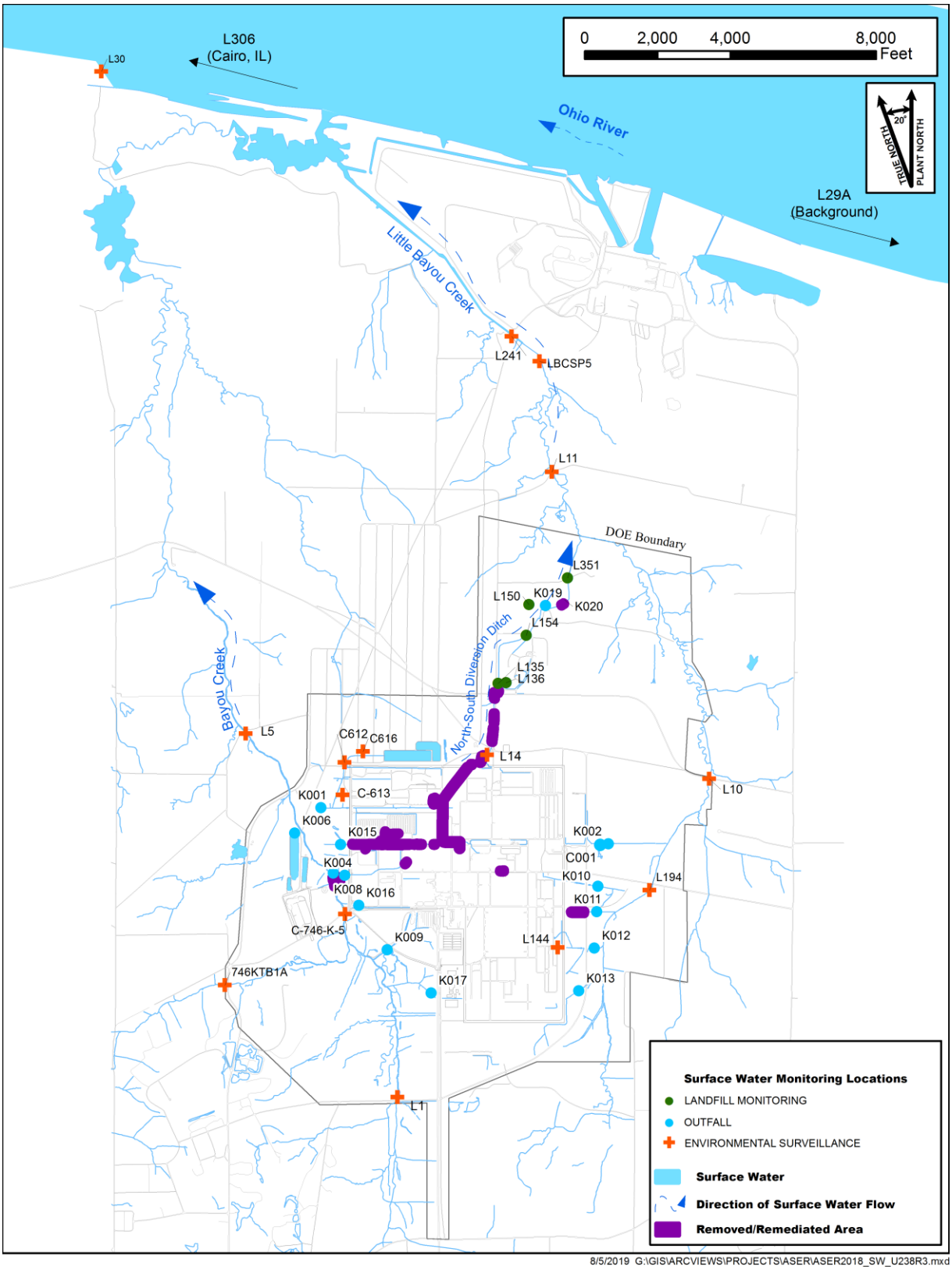

Figure 4.4. Surface Water Monitoring Locations

Gross alpha and beta analysis is performed at each environmental surveillance surface water location and locations near KPDES-permitted outfalls. If the gross alpha and beta analysis results are greater than 14 pCi/L and 300 pCi/L, respectively, a full isotopic analysis is performed. These values are calculated based on a concentration that would account for 10% of the DCS for common radionuclides at the Site. If, by the end of the CY, isotopic analysis has not been performed at a given location, then isotopic analysis for radionuclides is performed on the final sample within the CY to provide data for trending. Monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

Locations from which the maximum detected uranium isotopes were collected are just downstream of K015 (location named K015ERPP) for uranium-234, just downstream of K011 (location named K011ERPP) for uranium-235, and K015ERPP for uranium-238 (see Figure 4.4).

Sampling for surface water runoff at the C-746-S&T and C-746-U Landfills (L135, L136, L150, L154, and L351) is permit-driven and analyzed for alpha activity and beta activity.

In addition to surface water monitoring conducted under DOE Orders, the KPDES permit, and the solid waste landfills permit, surface water monitoring is also conducted as a separate monitoring program under CERCLA for the Northeast Plume Containment System effluent via outfall C001. This outfall is monitored for technetium-99 according to the Remedial Action Work Plan for Optimization of the Northeast Plume Interim Remedial Action (DOE 2018m). The highest surface water result for technetium-99 detected was found at C001. C001 is not used for calculating dose because it is a project-specific effluent and is not indicative of a body of water that a person could enter. No other technetium-99 results were detected in surface water at a location other than C001; therefore, technetium-99 is not used in dose calculation. Relocation of the two Northeast Plume extraction wells upgradient, as part of the optimization of the interim remedial action (see Section 6), has placed the wells where slightly higher technetium-99 results have been observed in area monitoring wells when compared to technetium-99 results in area monitoring wells in proximity to the previously used extraction wells. As such, a slight increase in technetium-99 in the extracted groundwater is not unexpected. The presence of technetium-99 was evaluated and determined not to pose potential threat to human health or the environment upon surface discharge as documented in the Record of Decision for Interim Remedial Action at the Northeast Plume (DOE 1995b). Additional monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

4.1.6.2 Drinking water

Surface water from the Paducah Site is not consumed by people as a drinking water source; however, it eventually is discharged into the Ohio River, which is used as a public drinking water source. Cairo, Illinois, is the closest drinking water system (approximately 30 miles downstream) that uses water downstream of the Paducah Site effluents. Cairo, Illinois, is located at the confluence of the Ohio and Mississippi Rivers. No radionuclides were detected near the surface water collection inlet at Cairo during CY 2018. The maximum beta activity detected was 6.06 pCi/L. Alpha activity was not detected above analysis detection limit.

The drinking water pathway dose was calculated where a maximally exposed individual is assumed to consume water from the public drinking water supply at Cairo, Illinois (L306). For the dose estimate, because no radionuclides were detected, a value of 0.0 mrem/year was used in the dose calculation.

Most of the individuals within a 50-mile radius of the Paducah Site do not obtain their daily drinking water from sources downgradient of the Paducah Site (see Sections 4.1.4 and 6.2). For 2018, therefore, an estimated collective dose has been calculated by multiplying the dose to the maximally exposed individual from annual ingestion of drinking water from the Cairo supply (prior to treatment) by the estimated number

of residents of Cairo in 2010 (2,830 persons) (Moonshadow Mobile 2015), which resulted in a representative collective dose of 0.0 person-rem/yr.

4.1.6.3 Incidental ingestion of surface water

Dose to the hypothetical maximally exposed individual is calculated based on incidental ingestion of surface water due to swimming in Bayou and Little Bayou Creeks and their tributaries (including outfall locations).[5] The assumptions based on *Methods for Conducting Risk Assessments and Risk Evaluations* are that a hypothetical recreator may swim 45 days a year, for 2.6 hours a day, with an incidental ingestion of 0.05 liters per hour and be in different locations throughout the wildlife management area (DOE 2018a). The highest monthly surface water results from the various sampling locations are utilized to calculate the bounding dose to the maximally exposed individual. The annual dose to the maximally exposed individual from incidental ingestion of surface water is 0.067 mrem/year.

Collective dose is not calculated for the incidental ingestion pathway because it is unlikely that a population of individuals would repeatedly swim in either Bayou or Little Bayou Creeks. This pathway is more likely to involve individuals; therefore, it is more suited for the maximally exposed individual dose calculation.

Table 4.4 summarizes the maximum isotopic detections of radionuclides at the surface water sampling locations and KPDES-permitted outfalls previously described. These maximum results are used to calculate dose based on incidental ingestion of surface water.

Table 4.4. Maximum Detected Radionuclides in 2018 Surface Water Samples

Isotope	Maximum Detect
Technetium-99 (pCi/L)	5.78E+01*
Uranium-234 (pCi/L)	1.33E+01
Uranium-235 (pCi/L)	2.69E+00
Uranium-238 (pCi/L)	4.80E+01

*Technetium-99 detects were found only at location C001. C001 sampling results are not used for calculating dose of incidental ingestion of surface water because it is a direct discharge of a treatment system and not representative of waters that a person may swim in; therefore, this sampling result for technetium-99 is not used in dose calculation.

4.1.6.4 Landfill leachate

Leachate collected from the C-746-U and C-746-S Landfills is sampled routinely and compared to DOE Order 458.1 limits. This data is used to determine programmatic management of landfill leachate. Leachate is treated and discharged through permitted outfalls at the site which are also monitored for compliance with permit limits. Additional monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

[5] The dose to the maximally exposed individual is a conservative estimate because the derivation of this dose is based on swimming, which is an unlikely activity for both Bayou and Little Bayou Creeks. For example, in an interview with the manager of the WKWMA, the manager noted that any water contact would be brief and be limited to wading across creeks. In a Health Assessment, the Agency for Toxic Substances and Disease Registry stated, "there is very little swimming, wading, or other human activity in Bayou and Little Bayou Creeks." Finally, the Kentucky Department of Fish and Wildlife Resources did not identify swimming (as compared to limited fishing and traversing incidental to hunting) as a recreational use of Little Bayou or Bayou Creeks in 1995 or 2014.

4.1.6.5 Groundwater

DOE has numerous groundwater monitoring wells, which are more fully described in Chapter 6. Groundwater wells that supplied drinking water to residents in the water policy area downgradient of the Paducah Site have been abandoned or taken out of service and the houses are provided with public drinking water; therefore, there is no groundwater drinking water source as an exposure route. Because groundwater is not used as a drinking water source, it is not considered in the calculation of dose to the maximally exposed individual. Similarly, groundwater as a drinking water source is not considered in the calculation of cumulative dose to the surrounding population.

4.1.7 Sediment Monitoring and Estimated Dose

Sediment is an important constituent of the aquatic environment. Radionuclides transported by water can adsorb onto suspended organic and inorganic solids or be assimilated by plants and animals. Suspended solids, dead biota, and excreta settle to the bottom and become part of the organic substrata that support the bottom-dwelling community of organisms. Thus, sediments can play a significant role in aquatic ecological impacts by serving as a repository for radioactive substances that pass via bottom-feeding biota to the higher trophic levels.

A single sediment sample can represent information that would require a large number of water samples, spaced over a period of time, to reconstruct. Sediment acts to collect, concentrate, and store specific kinds of contaminants at specific locations. Concentrations of contaminants in sediments represent integrated measures of aqueous contaminant concentrations over some preceding period of time.

In previous years, collective dose for annual incidental ingestion of sediment was not estimated because it was not a plausible exposure for residents who reside within 50 miles of the Paducah Site. The pathway was more likely to involve individuals; therefore, it was more suited for the maximally exposed individual dose calculation.

In order to be consistent with the estimated collective dose for direct radiation, an estimated collective dose has been calculated by multiplying the dose to the maximally exposed individual from incidental ingestion of sediment by a total estimated number of visitors hiking within the WKWMA annually (150 persons), which resulted in a representative collective dose of 0.0081 person-rem/yr (DOE 2018a).

4.1.7.1 Sediment surveillance program

Sediment sampling at the Paducah Site in CY 2018 included radiological and nonradiological constituents (FRNP 2018a). This sampling occurred in April, May, June, and December 2018. Sampling locations have been selected to facilitate the site-specific radiation exposure pathway analysis and to provide an indication of the accumulation of undissolved radionuclides in the aquatic environment (Figure 4.5).

Locations were prioritized for areas of public access, introduction of plant effluents to the environment, any unplanned release, and verification of the effectiveness of the Paducah Site effluent monitoring. Areas removed/remediated as part of a 2010 removal action for contaminated sediment associated with the Surface Water Operable Unit are denoted on the figure (DOE 2011b).

Sediment radiological analytical results are shown in Table 4.5 (see Section 5.3 for discussion related to nonradiological sediment sampling) and also may be found on the PEGASIS website at https://pegasis.pad.pppo.gov/. The radiological results for CY 2018 are similar in magnitude to those measured during previous years. Figure 4.5 shows the sampling locations and five year trending for the radionuclide that has historically been the highest at sediment monitoring locations sampled for

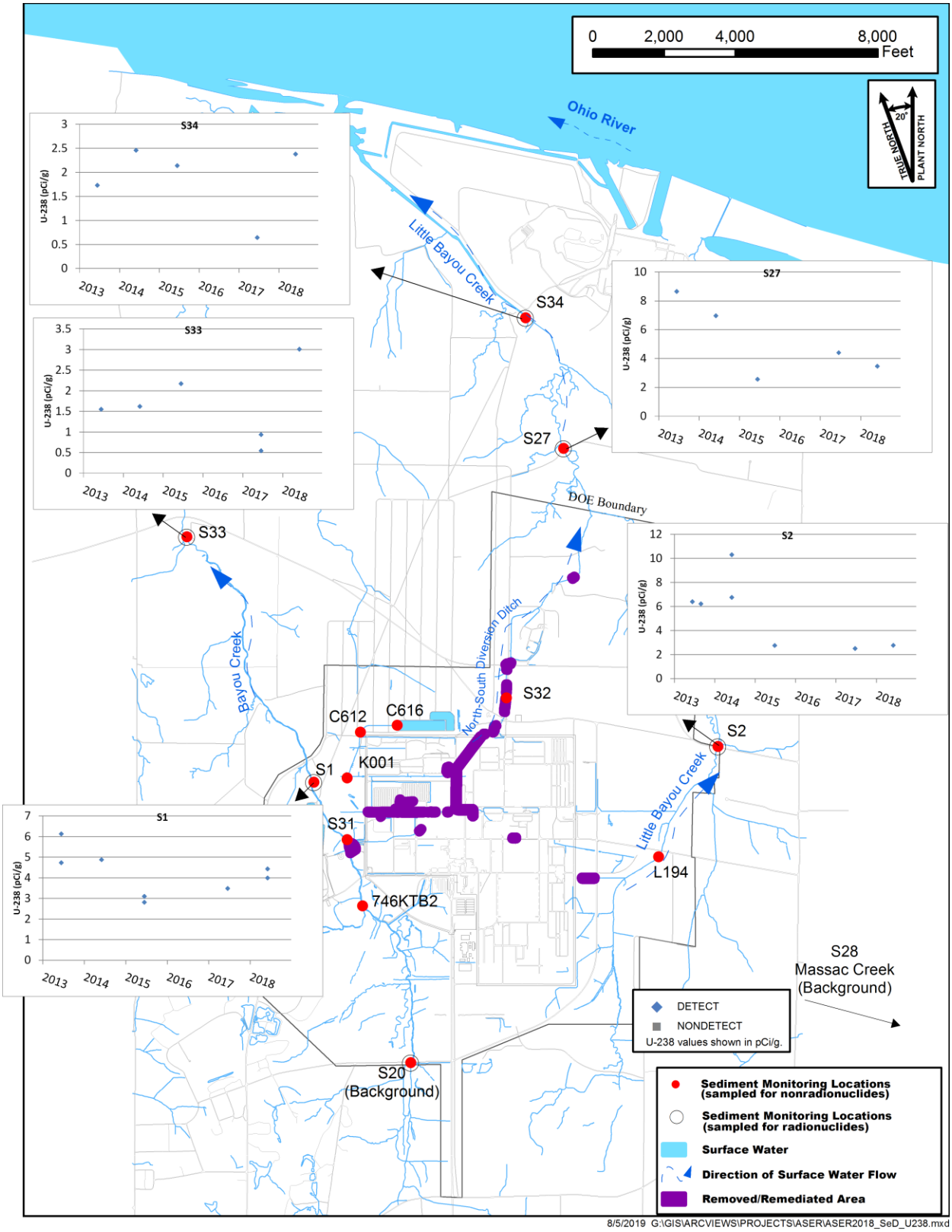

Figure 4.5. Sediment Monitoring Locations with Uranium-238 Trends

Table 4.5. Radiological Activities for Sediment Sampling[a]

Parameter	S1	S1 (duplicate)	S2	S20 (background)	S27		S33	S34
Alpha activity	1.67E+01	1.67E+01	1.33E+01	1.22E+01	1.77E+01		1.69E+01	1.61E+01
Beta activity	1.99E+01	2.42E+01	2.42E+01	2.67E+01	1.65E+01		3.00E+01	2.18E+02
Americium-241	-1.79E-01[b]	5.61E-03[b]	2.52E-01[b]	-9.29E-02[b]	-2.47E-02[b]		-6.75E-02[b]	2.76E-03[b]
Cesium-137	5.78E-02	3.67E-02[b]	1.22E-02[b]	4.23E-03[b]	6.75E-03[b]		1.55E-01	2.68E-02[b]
Neptunium-237	6.89E-02[b]	2.29E-01[b]	2.56E-02[b]	-1.03E-01[b]	-1.59E-02[b]		-1.56E-01[b]	-3.10E-02[b]
Plutonium-238	-5.23E-03[b]	1.69E-01[b]	2.26E-01[b]	1.14E-02[b]	2.31E-01[b]		6.61E-02[b]	1.13E-01[b]
Plutonium-239/240	1.83E-01[b]	-4.67E-02[b]	2.14E-02[b]	7.57E-02[b]	2.83E-01[b]		-4.17E-02[b]	2.84E-01[b]
Technetium-99	3.97E+00	6.20E+00	1.85E+00[b]	-1.35E-01[b]	1.66E+00[b]		3.03E+00[b]	7.88E-01[b]
Thorium-230	7.40E-01	1.41E+00	1.10E+00	9.57E-01	1.60E+00		1.00E+00	1.49E+00
Total Uranium	7.14E+00	7.45E+00	3.83E+00	1.96E+00	4.89E+00		5.52E+00	3.47E+00
Uranium-234	2.85E+00	2.56E+00	5.09E-01[b]	5.35E-01[b]	1.04E+00		2.33E+00	9.35E-01
Uranium-235	2.95E-01	4.68E-01[b]	5.66E-01	3.50E-01[b]	3.82E-01[b]		1.79E-01[b]	1.57E-01[b]
Uranium-238	3.99E+00	4.43E+00	2.76E+00	1.07E+00	3.46E+00		3.01E+00	2.38E+00

[a] Units are in pCi/g for all.
[b] Result reported at concentrations less than the laboratory's reporting limit. Negative values are possible and observed regularly with radiological data. Negative results may be reported due to a statistical determination of the counts seen by a detector, minus a background count (DOE 2018a).

radionuclides. Location S28 provides background concentrations for nonradiological sediment sampling; Location S20 provides background concentrations for radiological sediment sampling. Location S1 is located on Bayou Creek within the DOE boundary surrounding the Paducah Site. Location S2 is located downstream at Little Bayou Creek near the DOE boundary. Location S27 and S34 are located within Little Bayou Creek just north of the DOE Paducah Site boundary. Location S33 is located within Bayou Creek north of the DOE boundary. Overall, uranium activity is above background in Little Bayou Creek and Bayou Creek near and downstream of the plant site.

4.1.7.2 Sediment dose

For the purpose of calculating dose to the hypothetical maximally exposed individual, it is assumed that exposure to contaminated sediment in Bayou Creek and Little Bayou Creek could occur during hunting or other recreational activities. Exposure is possible through incidental ingestion of contaminated sediment. The ingestion assumption consists of an adult individual (i.e., an Adult Recreational User) who would wade around at one creek location every other day during the hunting season (104 days/year) and ingest a small amount of sediment during each visit (100 mg/day). A dose then is calculated based on the radionuclide activity and the amount of exposure via ingestion. Exposure is calculated using the methods presented in the *Methods for Conducting Risk Assessments and Risk Evaluations* (DOE 2018a), which includes the ingestion, inhalation, and external gamma pathways. Table A.8 of that document provides site-specific soil screening levels for receptors due to site-related radionuclides. Results from background location S20 are subtracted from other sample results to arrive at a dose associated with site releases. The downstream location with the maximum dose is assumed to represent the dose received from this pathway by the maximally exposed individual from the exposure scenario.

Doses are calculated for ingestion of sediments for both Bayou Creek and Little Bayou Creek using the radiological results for sediment surveillance samples for CY 2018. The highest annual dose was calculated to be at location S1 (0.054 mrem/year), downstream at Little Bayou Creek, near the Little Bayou Creek/North-South Diversion Ditch confluence. This dose calculation is based on the assumption that a person continually returns to the same location (i.e., S1). A comparison of sediment sampling data is provided in Table 4.5. Dose results for sediment sample locations are provided in Table 4.6.

Table 4.6. Average Annual Dose Estimates for CY 2018 Incidental Ingestion of Sediment

	Total Effective Dose (mrem/year)—Sediment Ingestion										
Location	**Am-241**	**Cs-137**	**Np-237**	**Pu-238**	**Pu-239/ Pu-240**	**Tc-99**	**Th-230**	**U-234**	**U-235**	**U-238**	**Total (mrem)**
S20 (background)[b]	0.00E+00	8.51E-04	0.00E+00	1.08E-04	7.76E-04	0.00E+00	8.32E-03	1.04E-03	1.50E-02	9.64E-03	3.57E-02
S1[b]	0.00E+00	8.66E-03	9.61E-03	6.65E-04	0.00E+00	1.58E-04	1.03E-03	4.25E-03	1.35E-03	2.83E-02	***5.40E-02***
S2[b]	2.62E-03	1.60E-03	1.65E-03	2.02E-03	0.00E+00	5.76E-05	1.24E-03	0.00E+00	9.27E-03	1.52E-02	3.37E-02
S27[b]	0.00E+00	5.07E-04	0.00E+00	2.07E-03	2.13E-03	5.17E-05	5.59E-03	9.86E-04	1.37E-03	2.15E-02	3.42E-02
S33[b]	0.00E+00	3.03E-02	0.00E+00	5.16E-04	0.00E+00	9.44E-05	3.74E-04	3.51E-03	0.00E+00	1.75E-02	5.23E-02
S34[b]	2.87E-05	4.54E-03	0.00E+00	9.58E-04	2.14E-03	2.45E-05	4.63E-03	7.81E-04	0.00E+00	1.18E-02	2.49E-02
Net Exposure from Paducah Site to the Maximally Exposed Individual[a,b,c,d] (Downstream Little Bayou) =											**5.40E-02**

[a] Maximum allowable exposure is 100 mrem/year for all contributing pathways and 25 mrem/year from one source (DOE Order 458.1).
[b] Radionuclide dose from S20 is considered background and has been subtracted from Paducah Site-related doses. If location dose is less than background dose or less than zero, the dose is specified as 0.00E+00 mrem/year.
[c] Dose calculated as ratio of listed dose for Adult Recreator in Table A.8 in *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant* (DOE 2017a2018a)*Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant* (DOE 2018a), which includes the ingestion, inhalation, and external gamma pathways.
[d] When more than one sample is present at the listed location, the doses of each sample are averaged.

4.1.8 Terrestrial Environment Monitoring and Estimated Dose

Wildlife and farm-raised animal products, including meat, eggs, and milk, may become contaminated through animal ingestion of contaminated water, sediment, other animals, or through direct contact with contaminated areas. The subsequent ingestion of these products can lead to public dose. As discussed earlier, a portion of the airborne radionuclides is estimated to be deposited in soil, ingested by animals, taken up by food crops, and ground surface pathways including consumption of vegetables, milk, and meat. Irrigation and deposition through waterborne radionuclides is an incomplete pathway because municipal water is used at nearby residences for household purposes (including activities such as irrigation of crops and lawns).

4.1.9 Wildlife

Wildlife from the DOE property have been sampled in past years for nonradiological and radiological constituents. Deer monitoring was performed annually for many past years and data was utilized for site dose assessment. During FY 2011, DOE performed an extensive review of data sets from 20 years of deer harvesting events. As a result of the 2011 review, DOE eliminated the deer harvesting in 2012 because of a downward trend and a continued lack of detection in the results, as well as an overall downward trend in the concentration of contaminants found at the Paducah Site due to remediation efforts. This exposure route and associated dose has been captured in the food chain models associated with the CAP-88 PC air program.

4.1.10 Direct Radiation Monitoring and Estimated Dose

4.1.10.1 Direct radiation surveillance

External radiation exposure from DOE's operations at the Paducah Site potentially contributes to the overall dose to the public. External radiation exposure is defined as exposure attributed to radioactive sources outside the body (e.g., cosmic gamma radiation). Sources of external radiation exposure at the Paducah Site include the cylinder storage yards, the operations inside the cascade building, and small items such as instrument calibration sources. Cylinder storage yards have the largest potential for a dose to the public because of their proximity to publicly accessible areas.

The external gamma and neutron radiation monitoring program is designed to provide data on external radiation exposure from DOE operations to members of the public. The primary factor in selecting the monitoring locations was the potential for a member of the public to be exposed to external radiation.

Secondary factors in selecting monitoring locations were accessibility and representative exposure potentially received by members of the public and area monitoring for individuals passing through the DOE site. In 2018, environmental thermoluminescent dosimeters (TLDs) with a calcium fluoride and lithium fluoride matrix were placed at the monitoring locations and collected and analyzed quarterly for a period of one year. Optically stimulated luminescence dosimeters were used to monitor for neutron radiation. These monitoring locations are shown in Figure 4.6. Monitoring results indicate that 10 of 51 locations were consistently above background levels, as reported in the *Annual Report on External Radiation Monitoring for Calendar Year 2018, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (FRNP 2019e). These locations were adjacent to or in close proximity to publicly accessible areas in the vicinity of UF_6 cylinder storage yards. Because security protocols prohibited the public from gaining prolonged access to the UF_6 cylinder storage yards, the potential radiation doses calculated at or in close proximity to the fence are not realistic.

4.1.10.2 Direct radiation dose

Due to Paducah Site security protocols in CY 2018, no members of the public routinely were allowed prolonged access to UF_6 cylinder storage yards. The external radiation doses measured by TLDs in areas accessible to the public were not statistically above background; however, the effective dose potentially received by a member of the public passing through accessible portions of the DOE Reservation would receive 5 mrem/year in a scenario where areas of highest exposure are visited 80 hours/year. In 2018, TLD-14 and TLD-40 represented the closest locations that would be accessible to the public. TLD-14, which is near Harmony Cemetery, located north of the plant security fence and south of Ogden Landing Road, represents the nearest location routinely accessible by the public. Measurements at this location indicated external radiation doses statistically equivalent to the background radiation level. In 2018, TLD-40 located on the DOE Reservation boundary with the DOE-leased WKWMA area off of Dyke Road also indicated external radiation dose measured to be slightly above background levels, but well below the DOE limit of 100 mrem/year. The maximally exposed individual at the private residences adjacent to the Paducah Site was calculated to be at background levels.

For 2018, an estimated collective dose has been calculated by multiplying the dose to the maximally exposed individual from direct radiation by a total estimated number of visitors hiking within the WKWMA annually (150 persons), which resulted in a representative collective dose of 0.75 person-rem/yr (DOE 2018a).

4.1.10.3 Cumulative dose calculation

This section presents the calculated radiological doses to individuals and the surrounding population from atmospheric and liquid releases from the Paducah Site, as well as from direct radiation. Table 4.7 provides a summary of the radiological dose for 2018 from the Paducah Site that could be received by a member of the public (i.e., the maximally exposed individual) assuming exposure from all relevant pathways. The largest contributor to the calculated dose is from direct radiation. Also contributing to the dose that could be received by the maximally exposed individual are atmospheric releases, including ingestion pathways considered in the AirDose EPA food chain modeling routines, incidental ingestion of surface water, ingestion of drinking water (in Cairo, Illinois), and incidental ingestion of sediments. The groundwater pathway from DOE sources is assumed to contribute no dose to the population, because DOE has supplied all potentially impacted residents with access to public water. The combined (internal and external) dose to an individual member of the public was calculated at 5.1 mrem/year. This level is well below the DOE annual dose limit of 100 mrem/year to members of the public and the EPA limit of 10 mrem airborne dose to the public. Table 4.7 also shows the percentage of the DOE annual dose limit that is received by the maximally exposed individual.

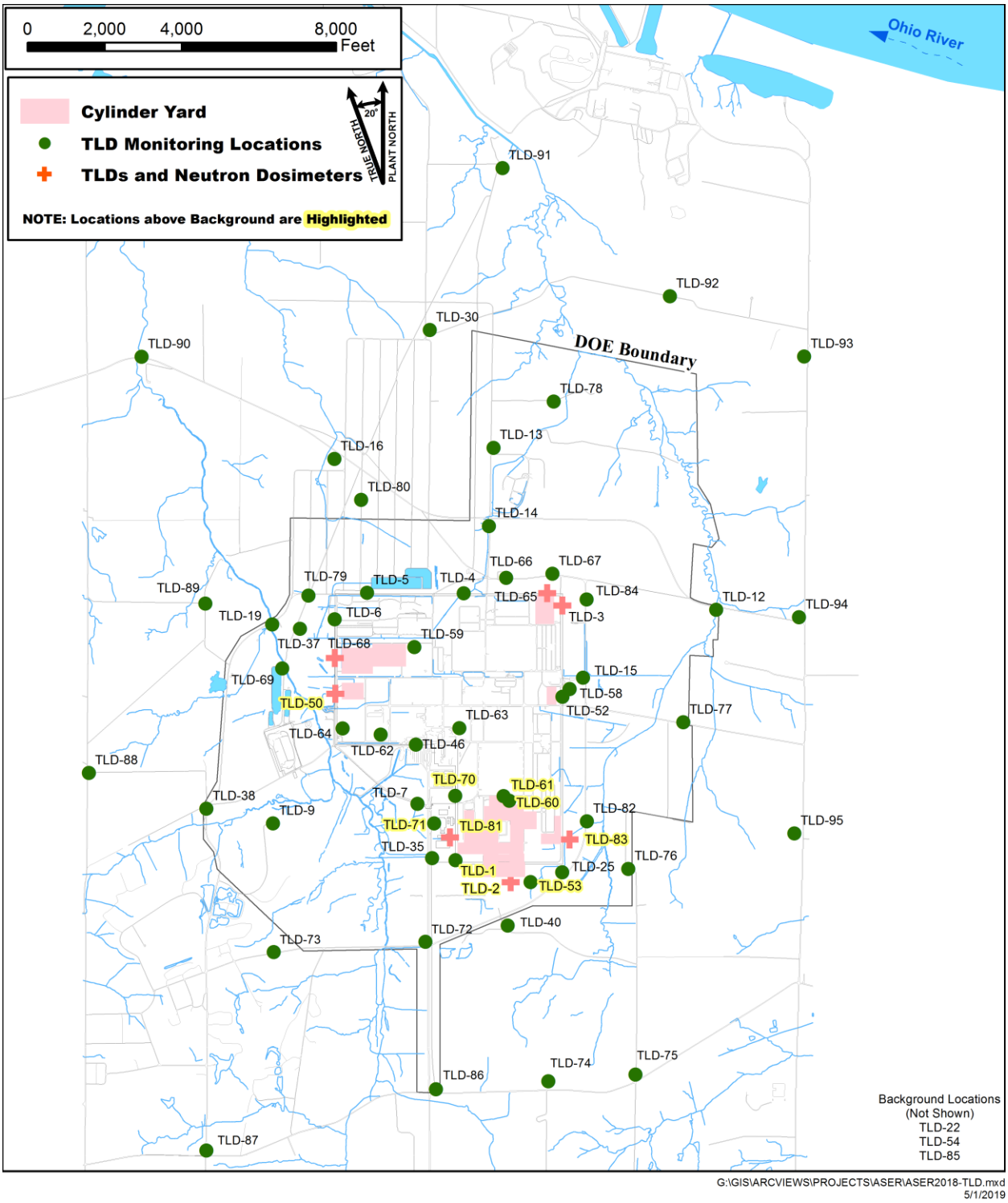

Figure 4.6. Dosimeter Locations in the Vicinity of the Paducah Site

Table 4.7. Summary of Potential Radiological Dose to the Maximally Exposed Individual from the Paducah Site for CY 2018[a]

Pathway[a]	Dose to Maximally Exposed Individual (mrem/year)	Percent of DOE 100 mrem/ year Limit	Estimated Collective (Population Dose) (person-rem/year)	Population within 50 miles
Air[c]	9.02E-05	0.00009%	6.01E-04	~534,116
Water[d]	[d]	[d]	[d]	[d]
Ingestion of drinking water[e]	0.0E+00	0.00%	0.0[f]	2,830
Incidental ingestion of surface water	6.7E-02	0.067%	[g]	[g]
Sediments (incidental ingestion)	5.4E-02	0.054%	8.1E-03[h]	150
Direct radiation	5.0E+00	5%	7.5E-01[h]	150
All Relevant Pathways[a]	**5.1E+00[b]**	**5.1%**	**7.6E-01**	

[a] Pathways defined in previous sections.
[b] Maximum allowable exposure from all sources is 100 mrem/year (DOE Order 458.1), which is consistent with 902 *KAR* 100:019, Section 10 (1)(a).
[c] Doses associated with atmospheric releases also include ingestion pathways considered in the AirDose EPA food chain modeling routines. DOE source emissions were from Northwest Plume Groundwater Treatment System, Northeast Plume Treatment Units, DUF_6 conversion Facility, Building Exhaust Vents, and Laboratory Hoods.
[d] Groundwater is not a viable pathway for the maximally exposed individual due to DOE's providing public water to downgradient residents.
[e] Ingestion of drinking water is assessed from the nearest surface water intake, Cairo, Illinois.
[f] Population dose for ingestion of drinking water from Cairo, Illinois, is based on a representative assumption using the estimated population of Cairo, Illinois, only.
[g] Incidental ingestion of surface water within plant creeks and ditches is not applicable for calculation of collective dose to residents who reside within 50 miles of the Paducah Site. Collective dose is not calculated for the incidental ingestion pathway due to the lack of a plausible exposure scenario. This pathway is more likely to involve individuals; therefore, it is more suited for the maximally exposed individual dose calculation.
[h] Population dose for direct radiation and incidental ingestion of sediment is based on a representative assumption using the estimated visitors hiking in WKWMA only.

Estimates of radiation doses presented in this report were calculated using the dose factors provided by DOE and EPA guidance documents and dose-based screening levels found within the Methods for Conducting Risk Assessments and Risk Evaluations (DOE 2018a).

The cumulative dose to members of the public residing within 50 miles of the Paducah Site has also been determined. Population dose was calculated for each exposure pathway and is summed to determine the cumulative population dose from all relevant pathways. The annual cumulative population dose, based on representative assumptions is 0.76 person-rem. Table 4.7 provides a summary of the representative population dose calculations.

4.1.11 Biota Monitoring and Estimated Dose

4.1.11.1 Biota surveillance

Radionuclides from both natural and man-made sources may be found in environmental media such as water, sediments, and soils. Contaminants may bioaccumulate in animals from eating contaminated feed, drinking contaminated water, and breathing contaminated air. Contaminants may bioaccumulate in fish when they eat contaminated foods and equilibrate with surrounding contaminated waters. Because plant and animal populations residing in or near these media or taking food or water from these media may be exposed to a greater extent than humans, DOE prepared a technical standard, DOE-STD-1153-2002, that provides methods and guidance to be used to evaluate doses from ionizing radiation to populations of aquatic animals, riparian animals (i.e., those that live along banks of streams or rivers), terrestrial plants, and terrestrial animals.

Because both measured concentrations and bioconcentration factors associated with radionuclides of concern at the Paducah Site in animals and fish are low, routine site-specific pathway assessments, to

include biota sampling, are not performed. Biota in the watersheds has been sampled extensively in the past, to the point that further collection of aquatic organisms could result in a deleterious effect on the aquatic community.

Sediment samples, as discussed in Section 4.1.7, are sampled annually for radionuclides. Surface water surveillance locations, as discussed in Section 4.1.6, are monitored quarterly.

4.1.11.2 Biota dose

Methods in the DOE Technical Standard, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2002, July 2002), were used to evaluate radiation doses to aquatic and terrestrial biota from CY 2018 operations. Doses were assessed for compliance with the limit in DOE Order 458.1 for native aquatic animal organisms (1 rad/day) and for compliance with the thresholds for terrestrial plants (1 rad/day), and for compliance with the thresholds for terrestrial animals (0.1 rad/day), as discussed in DOE-STD-1153-2002. The RESRAD-BIOTA computer model (version 1.8) is a calculation tool provided by DOE for implementing the technical standard and compares existing radionuclide concentration data from environmental sampling with biota concentration guide (BCG) screening values and to estimate upper bounding doses to biota.

Dose to biota was evaluated for Bayou and Little Bayou Creeks. Sample locations are shown in Figures 4.4 and 4.5. Locations L5 and S1 were used to represent water and sediment, respectively, in Bayou Creek. Data obtained from water sample location L11 and collocated sediment sample location S27 were used to represent water and sediment, respectively, in Little Bayou Creek. Outfalls 019 and 020, which flow into Little Bayou Creek, were not considered due to their intermittent flow. Also, L11 and S27 represent a location on Little Bayou Creek that is downstream of the confluence with the North-South Diversion Ditch. The creek at this point is more substantial and more likely to support aquatic life than those areas upstream. Data from water and sediment sampling locations on Bayou and Little Bayou Creeks were entered into the RESRAD-BIOTA model to calculate dose to biota from Paducah Site operations. The value for each radionuclide was divided by its corresponding BCG to calculate a partial fraction for each nuclide in each medium. Partial fractions for each medium were added to produce a sum of fractions. Exposures from the aquatic pathway may be assumed to be less than the aquatic dose limit from DOE Order 458.1 if the sum of fractions for the water plus that for the sediment is less than 1.0.

In accordance with the graded approach described in DOE-STD-1153-2002, a screening was conducted using the maximum radionuclide concentrations from surface waters and sediments. Table 4.8 summarizes the radiological dose to aquatic and terrestrial biota for Bayou Creek. Table 4.9 summarizes the radiological dose to aquatic and terrestrial biota for Little Bayou Creek. For each assessment, the limiting organism (i.e., the organism that is most sensitive to the potential radiological dose) is identified. The sum of fractions (or ratios) for each assessment and for the limiting organism was less than 1.0, indicating that the applicable BCGs were met for both the aquatic and terrestrial evaluations. These summed values are presented in the footnotes of each table. Additional monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

Table 4.8. Bayou Creek 2018 Evaluation of Dose to Aquatic and Terrestrial Biota[a]

	Aquatic Animal								
	Water				Sediment				Total
Radionuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	4.38E+02	N/A	Yes	5.61E-03[c]	6.80E+05	8.25E-09	No	8.25E-09
Cs-137	-4.91E-01[c]	1.05E+03	-4.69E-04	No	5.78E-02	4.93E+04	1.17E-06	No	-4.67E-04
K-40	-1.40E+01[c]	2.90E+03	-4.83E-03	No	N/A	5.79E+04	N/A	No	-4.83E-03
Np-237	4.57E-01[c]	6.85E+01	6.67E-03	Yes	2.29E-01[c]	7.86E+04	2.91E-06	No	6.67E-03
Pu-238	-9.26E-02[c]	1.76E+02	-5.26E-04	Yes	1.69E-01[c]	3.95E+06	4.28E-08	No	-5.26E-04
Pu-239[d]	6.79E-01[c]	1.87E+02	3.63E-03	Yes	1.83E-01[c]	7.05E+06	2.60E-08	No	3.63E-03
Tc-99	2.19E+00[c]	2.47E+06	8.87E-07	No	6.20E+00	4.59E+05	1.35E-05	No	1.44E-05
Th-230	N/A	2.57E+03	N/A	Yes	1.41E+00	2.74E+06	5.14E-07	No	5.14E-07
Th-234	0.00E+00[c]	2.66E+05	0.00E+00	Yes	N/A	4.32E+04	N/A	No	0.00E+00
U-234	3.80E-01[c]	2.02E+02	1.88E-03	Yes	2.85E+00	3.03E+06	9.40E-07	No	1.88E-03
U-235	2.25E-01[c]	2.18E+02	1.03E-03	Yes	4.68E-01[c]	1.10E+05	4.27E-06	No	1.04E-03
U-238	3.03E+00	2.24E+02	1.36E-02	Yes	4.43E+00	4.29E+04	1.03E-04	No	1.37E-02
Summed	-	-	2.09E-02	-	-	-	1.27E-04	-	2.11E-02
	Riparian Animal								
	Water				Sediment				Total
Radionuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	1.46E+03	N/A	No	5.61E-03[c]	5.15E+03	1.09E-06	Yes	1.09E-06
Cs-137	-4.91E-01[c]	4.27E+01	-1.15E-02	Yes	5.78E-02	3.13E+03	1.85E-05	Yes	-1.15E-02
K-40	-1.40E+01[c]	2.49E+02	-5.61E-02	Yes	N/A	4.42E+03	N/A	Yes	-5.61E-02
Np-237	4.57E-01[c]	1.16E+04	3.95E-05	No	2.29E-01[c]	7.63E+03	3.00E-05	Yes	6.95E-05
Pu-238	-9.26E-02[c]	5.51E+02	-1.68E-04	No	1.69E-01[c]	5.73E+03	2.95E-05	Yes	-1.39E-04
Pu-239[d]	6.79E-01[c]	6.22E+02	1.09E-03	No	1.83E-01[c]	5.87E+03	3.12E-05	Yes	1.12E-03
Tc-99	2.19E+00[c]	6.67E+05	3.28E-06	Yes	6.20E+00	4.14E+04	1.50E-04	Yes	1.53E-04
Th-230	N/A	1.39E+04	N/A	No	1.41E+00	1.04E+04	1.35E-04	Yes	1.35E-04
Th-234	0.00E+00[c]	3.80E+06	0.00E+00	No	N/A	4.32E+03	N/A	Yes	0.00E+00
U-234	3.80E-01[c]	6.84E+02	5.56E-04	No	2.85E+00	5.27E+03	5.41E-04	Yes	1.10E-03
U-235	2.25E-01[c]	7.37E+02	3.05E-04	No	4.68E-01[c]	3.79E+03	1.24E-04	Yes	4.29E-04
U-238	3.03E+00	7.57E+02	4.00E-03	No	4.43E+00	2.49E+03	1.78E-03	Yes	5.78E-03
Summed	-	-	-6.18E-02	-	-	-	2.84E-03	-	-5.90E-02
	Terrestrial Animal								
	Water				Sediment				Total
Nuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	2.02E+05	N/A	No	5.61E-03[c]	3.65E+25	1.54E-28	No	1.54E-28
Cs-137	-4.91E-01[c]	5.99E+05	-8.19E-07	No	5.78E-02	3.65E+25	1.58E-27	No	-8.19E-07
K-40	-1.40E+01[c]	1.93E+06	-7.25E-06	No	N/A	3.65E+25	N/A	No	-7.25E-06
Np-237	4.57E-01[c]	6.49E+06	7.04E-08	No	2.29E-01[c]	3.65E+25	6.27E-27	No	7.04E-08
Pu-238	-9.26E-02[c]	1.89E+05	-4.90E-07	No	1.69E-01[c]	3.65E+25	4.63E-27	No	-4.90E-07
Pu-239[d]	6.79E-01[c]	2.01E+05	3.38E-06	No	1.83E-01[c]	3.65E+25	5.01E-27	No	3.38E-06
Tc-99	2.19E+00[c]	1.54E+07	1.42E-07	No	6.20E+00	3.65E+25	1.70E-25	No	1.42E-07
Th-230	N/A	4.52E+05	N/A	No	1.41E+00	3.65E+25	3.86E-26	No	3.86E-26
Th-234	0.00E+00[c]	4.31E+06	0.00E+00	No	N/A	3.65E+25	N/A	No	0.00E+00
U-234	3.80E-01[c]	4.05E+05	9.39E-07	No	2.85E+00	3.65E+25	7.81E-26	No	9.39E-07
U-235	2.25E-01[c]	4.20E+05	5.35E-07	No	4.68E-01[c]	3.65E+25	1.28E-26	No	5.35E-07
U-238	3.03E+00	4.06E+05	7.46E-06	No	4.43E+00	3.65E+25	1.21E-25	No	7.46E-06
Summed	-	-	3.97E-06	-	-	-	4.38E-25	-	3.97E-06

Table 4.8. Bayou Creek 2018 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

	Terrestrial Plant								
	Water				Sediment				Total
Radionuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	6.80E+08	N/A	No	5.61E-03[c]	3.65E+26	1.54E-29	No	1.54E-29
Cs-137	-4.91E-01[c]	4.93E+07	-9.95E-09	No	5.78E-02	3.65E+26	1.58E-28	No	-9.95E-09
K-40	-1.40E+01[c]	5.79E+07	-2.42E-07	No	N/A	3.65E+26	N/A	No	-2.42E-07
Np-237	4.57E-01[c]	7.86E+07	5.82E-09	No	2.29E-01[c]	3.65E+26	6.27E-28	No	5.82E-09
Pu-238	-9.26E-02[c]	3.95E+09	-2.35E-11	No	1.69E-01[c]	3.65E+26	4.63E-28	No	-2.35E-11
Pu-239[d]	6.79E-01[c]	7.05E+09	9.64E-11	No	1.83E-01[c]	3.65E+26	5.01E-28	No	9.64E-11
Tc-99	2.19E+00[c]	4.59E+08	4.77E-09	No	6.20E+00	3.65E+26	1.70E-26	No	4.77E-09
Th-230	N/A	2.74E+09	N/A	No	1.41E+00	3.65E+26	3.86E-27	No	3.86E-27
Th-234	0.00E+00[c]	4.32E+07	0.00E+00	No	N/A	3.65E+26	N/A	No	0.00E+00
U-234	3.80E-01[c]	3.03E+09	1.25E-10	No	2.85E+00	3.65E+26	7.81E-27	No	1.25E-10
U-235	2.25E-01[c]	1.10E+08	2.05E-09	No	4.68E-01[c]	3.65E+26	1.28E-27	No	2.05E-09
U-238	3.03E+00	4.29E+07	7.06E-08	No	4.43E+00	3.65E+26	1.21E-26	No	7.06E-08
Summed	-	-	-1.68E-07	-	-	-	4.38E-26	-	-1.68E-07

Summed total ratio for limiting organism: 2.96E-02.
Summed water ratio for limiting organism: 2.68E-02.
Summed sediment ratio for limiting organism: 2.84E-03.
N/A in this table indicates radionuclide was not analyzed. Ratios were not included and not summed for radionuclides that were not analyzed.
[a] Bayou Creek evaluated based on 2018 maximum results for L5 and S1.
[b] BCG is the biota concentration guide value.
[c] Result was reported at concentrations less than the laboratory's reporting limit.
[d] Analytical data in PEGASIS are reported as Pu-239/240.

Table 4.9. Little Bayou Creek 2018 Evaluation of Dose to Aquatic and Terrestrial Biota[a]

	Aquatic Animal								
	Water				Sediment				Total
Radionuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	4.38E+02	N/A	Yes	-2.47E-02[c]	6.80E+05	-3.63E-08	No	-3.63E-08
Cs-137	N/A	1.05E+03	N/A	No	6.75E-03[c]	4.93E+04	1.37E-07	No	1.37E-07
Np-237	N/A	6.85E+01	N/A	Yes	-1.59E-02[c]	7.86E+04	-2.02E-07	No	-2.02E-07
Pu-238	N/A	1.76E+02	N/A	Yes	2.31E-01[c]	3.95E+06	5.85E-08	No	5.85E-08
Pu-239[d]	N/A	1.87E+02	N/A	Yes	2.83E-01[c]	7.05E+06	4.02E-08	No	4.02E-08
Tc-99	1.64E+01[c]	2.47E+06	6.64E-06	No	1.66E+0[c]	4.59E+05	3.62E-06	No	1.03E-05
Th-230	1.41E+00[c]	2.57E+03	5.49E-04	Yes	1.60E+00	2.74E+06	5.83E-07	No	5.49E-04
U-234	1.17E+00[c]	2.02E+02	5.79E-03	Yes	1.04E+00	3.03E+06	3.43E-07	No	5.79E-03
U-235	2.52E-01[c]	2.18E+02	1.16E-03	Yes	3.82E-01[c]	1.10E+05	3.49E-06	No	1.16E-03
U-238	1.77E+00[c]	2.24E+02	7.92E-03	Yes	3.46E+00	4.29E+04	8.07E-05	No	8.00E-03
Summed	-	-	1.54E-02	-	-	-	8.87E-05	-	1.55E-02
	Riparian Animal								
	Water				Sediment				Total
Nuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	1.46E+03	N/A	No	-2.47E-02[c]	5.15E+03	-4.80E-06	Yes	-4.80E-06
Cs-137	N/A	4.27E+01	N/A	Yes	6.75E-03[c]	3.13E+03	2.16E-06	Yes	2.16E-06
Np-237	N/A	1.16E+04	N/A	No	-1.59E-02[c]	7.63E+03	-2.08E-06	Yes	-2.08E-06
Pu-238	N/A	5.51E+02	N/A	No	2.31E-01[c]	5.73E+03	4.03E-05	Yes	4.03E-05
Pu-239[d]	N/A	6.22E+02	N/A	No	2.83E-01[c]	5.87E+03	4.82E-05	Yes	4.82E-05
Tc-99	1.64E+01[c]	6.67E+05	2.46E-05	Yes	1.66E+0[c]	4.14E+04	4.01E-05	Yes	6.47E-05
Th-230	1.41E+00[c]	1.39E+04	1.02E-04	No	1.60E+00	1.04E+04	1.53E-04	Yes	2.55E-04
U-234	1.17E+00[c]	6.84E+02	1.71E-03	No	1.04E+00	5.27E+03	1.97E-04	Yes	1.91E-03
U-235	2.52E-01[c]	7.37E+02	3.42E-04	No	3.82E-01[c]	3.79E+03	1.01E-04	Yes	4.43E-04
U-238	1.77E+00[c]	7.57E+02	2.34E-03	No	3.46E+00	2.49E+03	1.39E-03	Yes	3.73E-03
Summed	-	-	4.52E-03	-	-	-	1.96E-03	-	6.48E-03

Table 4.9. Little Bayou Creek 2018 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

	Terrestrial Animal								
	Water				Sediment				Total
Nuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	2.02E+05	N/A	No	-2.47E-02[c]	3.65E+25	-6.77E-28	No	-6.77E-28
Cs-137	N/A	5.99E+05	N/A	No	6.75E-03[c]	3.65E+25	1.85E-28	No	1.85E-28
Np-237	N/A	6.49E+06	N/A	No	-1.59E-02[c]	3.65E+25	-4.36E-28	No	-4.36E-28
Pu-238	N/A	1.89E+05	N/A	No	2.31E-01[c]	3.65E+25	6.33E-27	No	6.33E-27
Pu-239[d]	N/A	2.01E+05	N/A	No	2.83E-01[c]	3.65E+25	7.75E-27	No	7.75E-27
Tc-99	1.64E+01[c]	1.54E+07	1.07E-06	No	1.66E+0[c]	3.65E+25	4.55E-26	No	1.07E-06
Th-230	1.41E+00[c]	4.52E+05	3.12E-06	No	1.60E+00	3.65E+25	4.38E-26	No	3.12E-06
U-234	1.17E+00[c]	4.05E+05	2.89E-06	No	1.04E+00	3.65E+25	2.85E-26	No	2.89E-06
U-235	2.52E-01[c]	4.20E+05	5.99E-07	No	3.82E-01[c]	3.65E+25	1.05E-26	No	5.99E-07
U-238	1.77E+00[c]	4.06E+05	4.36E-06	No	3.46E+00	3.65E+25	9.48E-26	No	4.36E-06
Summed	-	-	1.20E-05	-	-	-	2.36E-25	-	1.20E-05
	Terrestrial Plant								
	Water				Sediment				Total
Nuclide	Concentration (pCi/L)	BCG[b] (pCi/L)	Ratio	Limiting Organism	Concentration (pCi/g)	BCG[b] (pCi/g)	Ratio	Limiting Organism	Ratio
Am-241	N/A	6.80E+08	N/A	No	-2.47E-02[c]	3.65E+26	-6.77E-29	No	-6.77E-29
Cs-137	N/A	4.93E+07	N/A	No	6.75E-03[c]	3.65E+26	1.85E-29	No	1.85E-29
Np-237	N/A	7.86E+07	N/A	No	-1.59E-02[c]	3.65E+26	-4.36E-29	No	-4.36E-29
Pu-238	N/A	3.95E+09	N/A	No	2.31E-01[c]	3.65E+26	6.33E-28	No	6.33E-28
Pu-239[d]	N/A	7.05E+09	N/A	No	2.83E-01[c]	3.65E+26	7.75E-28	No	7.75E-28
Tc-99	1.64E+01[c]	4.59E+08	3.57E-08	No	1.66E+00[c]	3.65E+26	4.55E-27	No	3.57E-08
Th-230	1.41E+00[c]	2.74E+09	5.14E-10	No	1.60E+00	3.65E+26	4.38E-27	No	5.14E-10
U-234	1.17E+00[c]	3.03E+09	3.86E-10	No	1.04E+00	3.65E+26	2.85E-27	No	3.86E-10
U-235	2.52E-01[c]	1.10E+08	2.30E-09	No	3.82E-01[c]	3.65E+26	1.05E-27	No	2.30E-09
U-238	1.77E+00[c]	4.29E+07	4.13E-08	No	3.46E+00	3.65E+26	9.48E-27	No	4.13E-08
Summed	-	-	8.02E-08	-	-	-	2.36E-26	-	8.02E-08

Summed total ratio for limiting organism: 1.74E-02.
Summed water ratio for limiting organism: 1.54E-02.
Summed sediment ratio for limiting organism: 1.97E-03.
N/A in this table indicates radionuclide was not analyzed. Ratios were not included and not summed for radionuclides that were not analyzed.
[a] Little Bayou Creek evaluated based on 2018 maximum results for L11 and S27.
[b] BCG is the biota concentration guide value.
[c] Result was reported at concentrations less than the laboratory's reporting limit.
[d] Analytical data in PEGASIS are reported as Pu-239/240.

4.2 CLEARANCE OF PROPERTY CONTAINING RESIDUAL RADIOACTIVE MATERIAL

This section addresses clearance of personal property (see glossary) containing residual radioactive material. The Paducah Site has begun efforts to transfer real property (see glossary), but clearance of real property has not yet taken place.

DOE contractors use the processes, guidelines, and limits found in DOE Order 458.1 and associated guidance for the clearance of property with residual radioactive material (see glossary). Release criteria for surface contamination limits as specified in DOE Order 458.1, *Radiation Protection of the Public and Environment*, are used for clearance of objects with the potential for surface contamination, while specific Authorized Limits have been derived to control whether items with potential volumetric contamination are released. Property potentially containing residual radioactive material will not be cleared from the Paducah Site unless the property is demonstrated to be within acceptable limits. Property clearance requirements are governed by procedures established by each DOE contractor.

In 2018, FRNP authorized, with concurrence from DOE, 447 releases of personal property that were surveyed for contamination. Several of these releases were in support of reuse and recycling efforts and deactivation operations. Multiple radiological surveys were performed to measure the radiological status of the property. Items released included, but were not limited to, heavy equipment, vehicles, containers, tanks, monitoring equipment, activated carbon, and batteries. If survey measurements exceeded 80% of the specified release limit, independent verification was conducted.

In 2018, SST authorized, with concurrence from DOE, 321 releases of personal property that were surveyed for surface contamination. Most of these were in support of SST operations including, but not limited to, vehicles, mowers, miscellaneous equipment and parts, furniture, electronics, and fire extinguishers. If survey measurements exceeded 80% of the specified release limit, independent verification was used to verify that no radioactive materials had been added or that results were below the appropriate release limit.

In 2018, MCS shipped off-site hydrofluoric acid produced by the DUF_6 Conversion Facility, which converts DUF_6 into uranium oxide and hydrofluoric acid. Each shipment must meet the Authorized Limit of less than 3 pCi/mL of total uranium activity. During 2018, 880,000 gal of hydrofluoric acid were shipped off-site, and the total uranium activity of each shipment was below the detection limit of 1.06 pCi/mL.

4.3 UNPLANNED RADIOLOGICAL RELEASES

There were no unplanned radiological releases in 2018.

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5. ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION

5.1 AIR MONITORING

No active emission points at the Paducah Site require nonradiological air monitoring.

5.2 SURFACE WATER MONITORING

At the Paducah Site, the Clean Water Act regulations were applied through issuance of a KPDES permit for effluent discharges to Bayou Creek and Little Bayou Creek. The KDOW issued KPDES Permit No. KY0004049 to DOE and FRNP for Outfalls 001, 002, 004, 006, 008, 009, 010, 011, 012, 013, 015, 016, 017,[6] 019, and 020. The permit combined outfalls that formerly were covered under both this permit and KPDES Permit KY0102083. In addition to the KPDES permit, a CERCLA outfall (C001) related to the Northeast Plume Pump-and-Treat operation discharges to surface water. Surface water from the C-613 Basin, a storm-water control facility that collects storm water runoff from scrapyards located in the northwestern portion of the Paducah Site, is sampled per the Northwest Storm Water Control Facility Operations and Maintenance Plan (DOE 2009) prior to discharge to Outfall 001. Further, KDWM specifies in landfill permit SW07300014, SW07300015, and SW07300045 that surface runoff will be analyzed to ensure that landfill constituents are not discharging into nearby receiving streams. Storm-water discharge from the KDWM-permitted solid waste landfill is sampled under the KPDES permit.

Surface water monitoring locations and the monitoring program under which they are sampled routinely at the Paducah Site are shown in Figure 5.1 and in Table 5.1, respectively. Figure 5.1 shows trends for TCE results in selected surface water monitoring locations over the last five years. Table 5.1 also shows the reporting for each of these programs. Permit exceedances are described in Chapter 2. Monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/ and are summarized in Table 5.2.

Project-specific surface water sampling for decommissioning and environmental remediation projects is not summarized within this report.

5.3 SEDIMENT MONITORING

Sediment monitoring locations are shown in Figure 4.5. Total PCBs (also listed as polychlorinated biphenyls in laboratory reports) were detected in sediment during 2018 ranging from 2.31 µg/kg to 358 µg/kg, within the acceptable risk range. According to *Methods for Conducting Risk Assessments and Risk Evaluations*, the no action level[7] for Total PCBs is 179 µg/kg, and the action level[8] is 17,900 µg/kg for the recreational user (DOE 2018a). The recreational user is used for comparison because it is the most reasonably anticipated scenario. Additional monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

[6] Permit Number KY0004049 also includes MCS as a permittee for Outfall 017.
[7] The no action level is the concentration that represents the lesser of an excess lifetime cancer risk of 10^{-6} and a hazard index of 0.1.
[8] The action level is the concentration that represents the lesser of an excess lifetime cancer risk of 10^{-4} and a hazard index of 3.

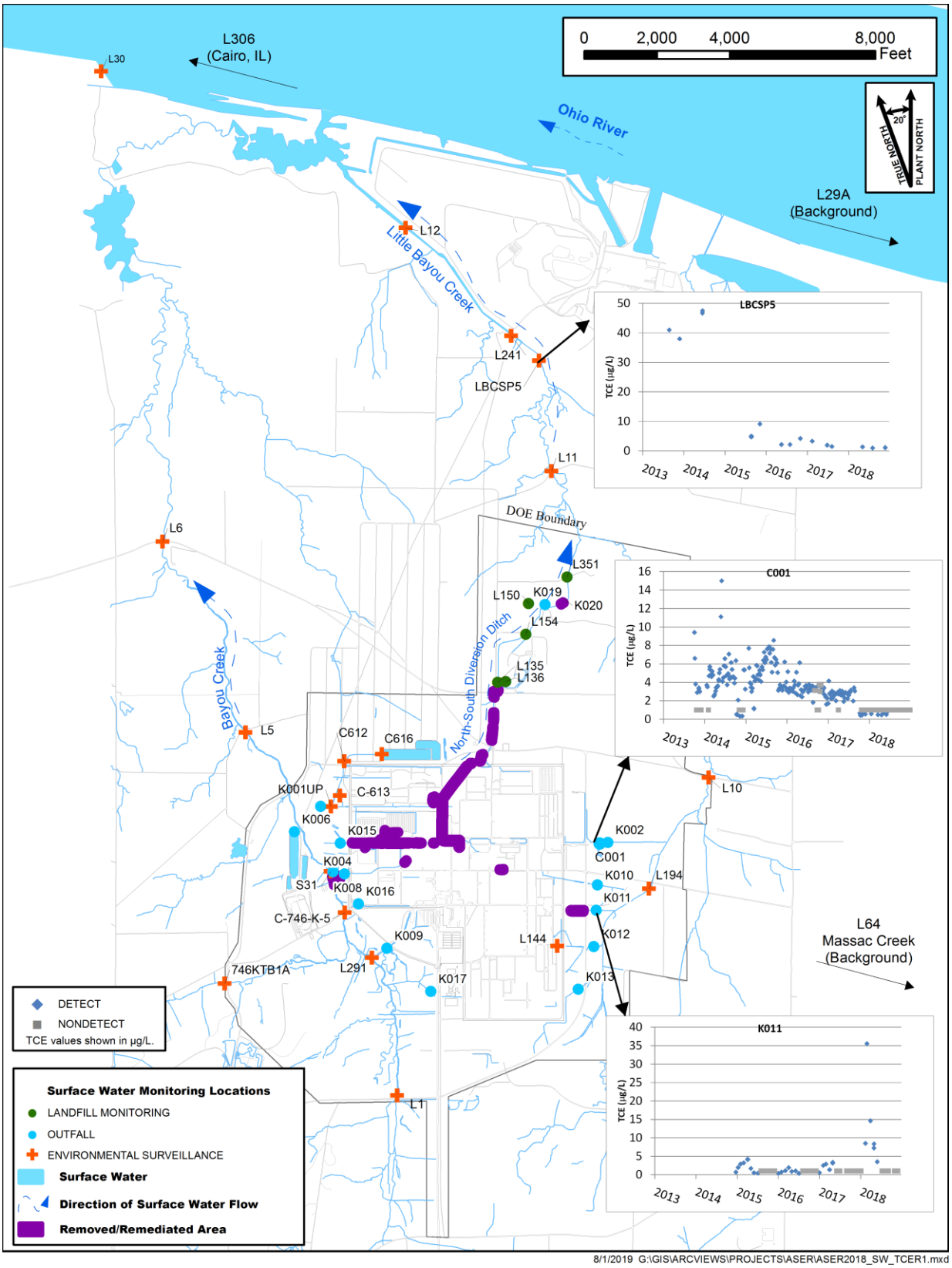

Figure 5.1. Surface Water and Seep Monitoring Locations with TCE Trends

Table 5.1. Summary of Surface Water Monitoring at the Paducah Site

Program and Reporting Location	Locations (see Figure 4.4)
Effluent Watershed Monitoring Program	
C-746-S and C-746-T Landfill Surface Water *Quarterly Compliance Monitoring Reports*: First Quarter 2018 (January—March) Second Quarter 2018 (April—June) Third Quarter 2018 (July—September) Fourth Quarter 2018 (October—December)	L135, L136, L154*
C-746-U Landfill Surface Water *Quarterly Compliance Monitoring Reports*: First Quarter 2018 (January—March) Second Quarter 2018 (April—June) Third Quarter 2018 (July—September) Fourth Quarter 2018 (October—December)	L150, L154*, L351
KPDES Discharge Monitoring Reports	K001, K002, K004, K006, K008, K009, K010, K011, K012, K013, K015, K016, K017, K019, K020
C-613 Northwest Storm Water Control Facility Reported to KDWM via electronic mail	C-613
Environmental Surveillance Watershed Monitoring Program	
Surface Water	746KTB1A, C612, C616, C746K-5, L1, L10, L11, L194, L241, L29A, L30, L306, L5, L14
Seep	LBCSP5
Northeast Plume Effluent *Semiannual FFA Progress Reports:* Second Half of FY 2018 (Data reported January–June 2018) First Half of FY 2018 (Data reported July–December 2018)	C001

*Location is listed for both C-746-S and C-746-T and for C-746-U.

Table 5.2. Ranges of Detected Analytes in 2018 Surface Water Samples

Analyte	Range
Anions	
Chloride (µg/L)	280–16,300
Sulfate (µg/L)	4,210–59,500
Wet Chemistry Parameters	
Biochemical Oxygen Demand (µg/L)	3,550–26,500
Chemical Oxygen Demand (µg/L)	34,700–505,000
Dissolved Solids (µg/L)	97,100–233,000
Hardness—Total as $CaCO_3$ (µg/L)	18,000–207,000
Suspended Solids (µg/L)	600–748,000
Total Organic Carbon (µg/L)	7,980–27,900
Total Solids (µg/L)	109,000–472,000
Volatile Organic Compounds	
Trichloroethene (µg/L)	0.34–35.5*

Table 5.2. Ranges of Detected Analytes in 2018 Surface Water Samples (Continued)

Analyte	Range
PCBs	
PCB-1248 (µg/L)	0.0636–0.0636
PCB-1260 (µg/L)	0.0332–0.122
Total PCBs (µg/L)	0.0332–0.122
Other Organics	
Oil and Grease (µg/L)	1,130–2,880
Metals	
Aluminum (µg/L)	22.2–1,930
Arsenic (µg/L)	2.81–3.12
Barium (µg/L)	46.5–56.9
Calcium (µg/L)	8,550–27,400
Copper (µg/L)	1.71–10.3
Iron (µg/L)	94.1–4,860
Lead (µg/L)	0.775–2.06
Magnesium (µg/L)	2,160–5,400
Manganese (µg/L)	39.9–457
Nickel (µg/L)	0.66–3.27
Phosphorous (µg/L)	21.3–567
Potassium (µg/L)	2,160–5,600
Sodium (µg/L)	844–35,500
Uranium (µg/L)	0.081–216
Zinc (µg/L)	8.11–151

*While above the max 2017 range, 35.5 µg/L is well below the historical max for TCE in surface water samples.

5.4 BIOTA MONITORING

Biological monitoring (i.e., fish or benthic macroinvertebrate sampling) was not required under the specifications listed in the KPDES permits.

5.4.1 Aquatic Life

Starting in 1987, aquatic or biological monitoring of Bayou Creek and Little Bayou Creek had been conducted following guidelines set forth in the Watershed Monitoring Plan (LATA Kentucky 2011). Requirements set forth in the Watershed Monitoring Plan followed conditions in the KPDES permit (KY0004049) and best management practices. Initially, the permit required sampling of fish and benthic macroinvertebrate in the receiving creeks, as well as chronic and acute toxicity sampling at the KPDES outfalls. After years of collecting fish and benthic macroinvertebrate samples, KDOW issued a new KPDES permit in 2009, eliminating the requirements for the fish and benthic macroinvertebrate sampling; however, the chronic and acute toxicity sampling remained a KPDES permit condition. In order to provide data for future ecological assessments, DOE continued the benthic macroinvertebrate sampling efforts through 2010. Benthic macroinvertebrate sampling was eliminated in 2011. Chronic and acute toxicity sampling remain in the KPDES permit. Chronic and acute toxicity testing are the two basic types of whole effluent toxicity testing that describe the aggregate toxic effects of the whole effluent wastewater discharge as measured by an organism's response upon exposure to the sample. These tests replicate the total effect of

environmental exposure of aquatic life to toxic pollutants in an effluent without requiring the identification of the specific pollutants.

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

5.5 FIRE PROTECTION MANAGEMENT AND PLANNING

Fire protection management and planning at the Paducah Site follows the *Wildland Fire Management Plan*, CP2-EP-1005. The program includes fire prevention and hazard mitigation efforts including, but not limited to, training, work restrictions, combustible vegetation controls, safe facility location, and fire protection design considerations. If a wildland fire were to occur, a multiagency response would be activated to bring all available firefighting and related emergency response functions to bear, to combat the fire promptly, minimizing the risk of fire exposure to the public, site personnel, and critical facilities and programs.

DOE's Deactivation and Remediation Contractor, FRNP, is responsible for wildland fire management of all DOE owned property, except for the 1,980 acres licensed to WKWMA. West McCracken Fire Department is responsible for the area licensed to WKWMA.

5.6 RECREATIONAL HUNTING AND FISHING

Permitted recreational activities were expanded in the DOE-owned land in WKWMA in 2012. Expanded activities included youth turkey hunting, horseback riding, hiking, dog training and trials, hunting with a gun for small game, increased bow hunting for deer, mountain biking, and nature hiking. Additional information regarding hunting seasons and hunting and fishing limits is available from the Kentucky Department of Fish and Wildlife Resources website http://fw.ky.gov/.

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6. GROUNDWATER PROTECTION PROGRAM

The Results of the Site Investigation Phase 1 in 1991 determined the primary off-site contaminants in the Regional Gravel Aquifer (RGA), the primary aquifer for local groundwater users, to be TCE and technetium-99 (CH2M HILL 1991). TCE was used until 1993 as an industrial degreasing solvent and technetium-99 is a fission by-product contained in nuclear power reactor returns that were brought on-site through 1976 for reenrichment of uranium-235 (DOE 2001). Known or potential sources of TCE and technetium-99 include former test areas, spills, leaks, buried waste, and leachate derived from contaminated scrap metal previously stored on-site.

Investigations of the on-site source areas of TCE at the Paducah Site are ongoing. The main source and highest concentration of TCE contamination in the groundwater is near the C-400 Cleaning Building. TCE has a low solubility and a higher density than water and is included in a chemical group referred to as dense nonaqueous-phase liquids. As a result of these characteristics, TCE typically sinks through the subsurface and may form pools in less permeable layers of the subsurface, as well as the base of the aquifer. The pooling makes treatment difficult because these pools constitute a continuous source of dissolved-phase contamination (i.e., plumes) deep within the aquifer.

Groundwater monitoring serves to detect the nature and extent of contamination (i.e., types of contaminants, concentration of contaminants) and to determine the movement of groundwater near the plant. Data obtained from groundwater monitoring supports the decision making process for the ultimate disposition of the contaminants. Figure 6.1 presents monitoring wells sampled in CY 2018 and shows the 2016 TCE plume associated with the Paducah Site (FPDP 2017). See Section 6.4 for additional information about the plumes associated with the Paducah Site.

For access to historical groundwater data, visit the PEGASIS website at https://pegasis.pad.pppo.gov/ to view data for monitoring wells and groundwater locations at the Paducah Site.

6.1 GEOLOGIC AND HYDROGEOLOGIC SETTING

The local groundwater flow systems at the Paducah Site include the following (from shallowest to deepest): (1) the Terrace Gravel flow system, (2) Upper Continental Recharge System, (3) RGA, and (4) the McNairy flow system. Additional water-bearing zones monitored at the Paducah Site are the Eocene Sands and the Rubble Zone (i.e., the weathered upper portion of the Mississippian bedrock). These components are illustrated on Figure 6.2.

Groundwater flow originates south of the Paducah Site within Eocene Sands and the Terrace Gravel. Groundwater within the Terrace Gravel discharges to local streams and recharges the RGA. Groundwater flow through the Upper Continental Recharge System predominantly is downward, also recharging the RGA. From the plant site, groundwater generally flows northward in the RGA toward the Ohio River, which is the local base level for the system. Flow in the McNairy beneath the Paducah Site also is northward to discharge into the Ohio River.

Additional information regarding the geology and hydrogeology of the Paducah Site can be found in the *Report of the Paducah Gaseous Diffusion Plant Groundwater Investigation Phase III* (available at https://eic.pad.pppo.gov/Search.aspx?accession=I-02500-0030) (MMES 1992). In 2016, a revision of the sitewide groundwater flow model was completed (DOE 2017).

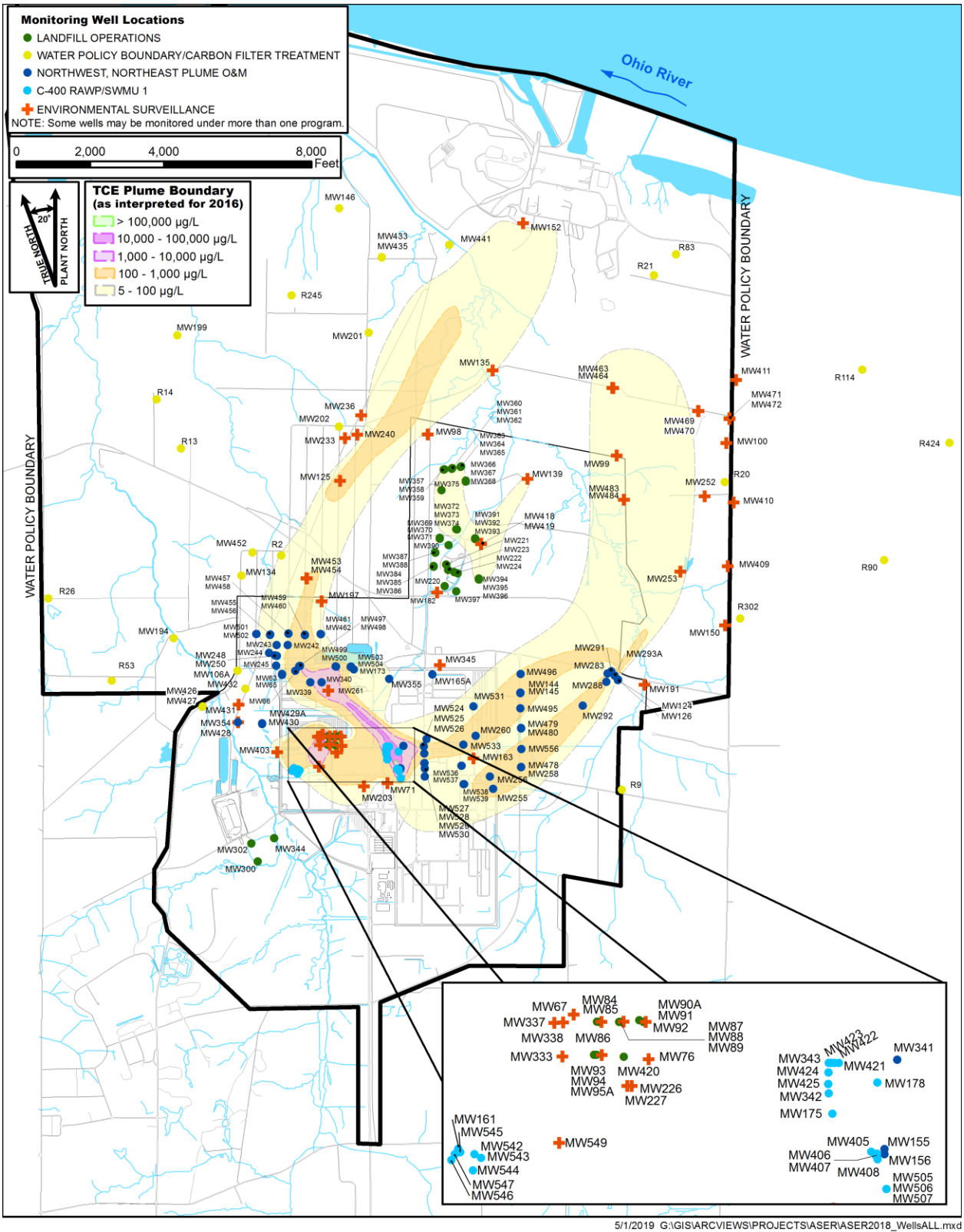


Figure 6.1. Monitoring Wells Sampled in CY 2018

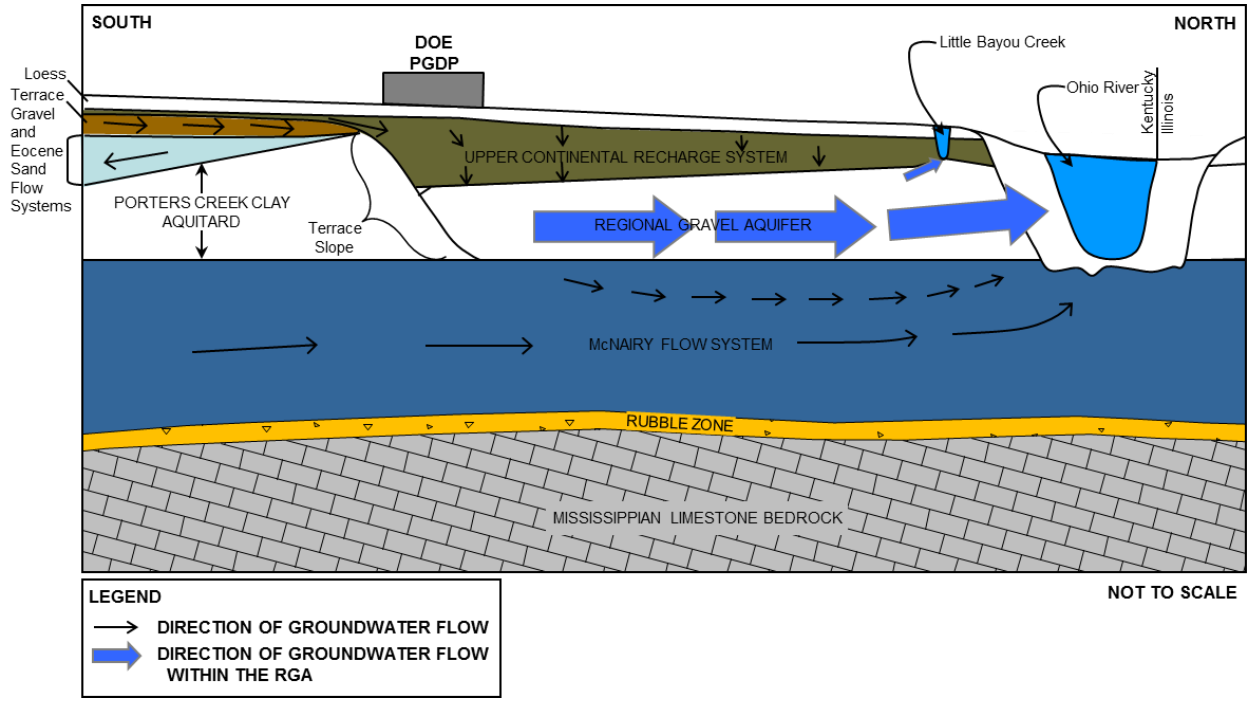


Figure 6.2. Paducah Site Groundwater Flow System and Water-Bearing Zones

6.2 USES OF GROUNDWATER IN THE VICINITY

The WKWMA and some lightly populated farmlands are in the immediate vicinity of the Paducah Site. Homes are sparsely located along rural roads in the vicinity of the site. Two communities, Grahamville and Heath, lie within 2 miles east of the plant.

Historically, groundwater was the primary source of drinking water for residents and businesses in the vicinity of the plant area. In areas where the groundwater either is known to be contaminated or has the potential to become contaminated in the future, DOE has provided water hookups to the West McCracken County Water District and pays water bills for affected residences and businesses. An educational mailer was developed in 2016 and has been mailed to residents annually since then in an effort to ensure public awareness of the groundwater contamination. Residential wells have been capped and locked (per license agreement between DOE and each resident; renewed every five years).

6.3 GROUNDWATER MONITORING PROGRAM

Monitoring wells are used extensively at the Paducah Site to assess the effect of plant operations on groundwater quality. The primary objectives of the groundwater monitoring program at the Paducah Site are obtaining data to determine baseline and/or current conditions of groundwater quality and quantity; demonstrating compliance with and implementation of all applicable regulations and DOE Orders; providing data to allow early detection of groundwater pollution or contamination; identifying existing and potential groundwater contamination sources and maintaining surveillance of these sources; and providing data for making decisions about waste disposal on land-based units and the management and protections of

groundwater resources. The groundwater monitoring program consists of routine compliance and facility monitoring designed to ensure protection of public health and the environment.

The sitewide approach is outlined in the following two documents related to groundwater monitoring: (1) Groundwater Protection Plan (FRNP 2018d); and (2) and the Paducah Site Environmental Monitoring Plan (FRNP 2018a). Over 200 monitoring wells and residential wells were sampled in accordance with DOE Orders and federal, state, and local requirements during 2018. Well sampling is included in several different monitoring programs, as shown in Table 6.1. Shown also in Table 6.1 are the number of wells sampled in each flow system and each program (note that some wells are sampled under more than one program) and the reporting locations for each of these programs. Monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

Table 6.1. Summary of Groundwater Monitoring at the Paducah Site

Program and Reporting Location	Number of Wells[a]					
	Terrace Gravel/ Eocene Sands	Upper Continental Recharge System	RGA	McNairy Flow System	Rubble Zone	Total
Groundwater Monitoring Program for Landfill Operations						
C-746-S and C-746-T Landfill Wells *Quarterly Compliance Monitoring Reports*: First Quarter 2018 (January–March) Second Quarter 2018 (April–June) Third Quarter 2018 (July–September) Fourth Quarter 2018 (October–December)	0	4	14	0	0	18[c]
C-746-U Landfill Wells *Quarterly Compliance Monitoring Reports*: First Quarter 2018 (January–March) Second Quarter 2018 (April–June) Third Quarter 2018 (July–September) Fourth Quarter 2018 (October–December)	0	7	12	0	0	19
C-404 Landfill Wells (required by permit) *Semiannual C-404 Groundwater Monitoring Reports:* C-404 Hazardous Waste Landfill May 2018 Semiannual Groundwater Report (October 2017–March 2018) C-404 Hazardous Waste Landfill November 2018 Semiannual Groundwater Report (April 2018–September 2018)	0	4	5	0	0	9
C-404 Landfill Wells (Not Committed)	0	0	12	0	0	12

Table 6.1. Summary of Groundwater Monitoring at the Paducah Site (Continued)

Program and Reporting Location	Number of Wells[a]					
	Terrace Gravel/ Eocene Sands	Upper Continental Recharge System	RGA	McNairy Flow System	Rubble Zone	Total
Groundwater Monitoring Program for Landfill Operations (Continued)						
C-746-K Landfill Wells *Semiannual FFA Progress Reports:* Second Half of FY 2018 (Data reported January–June 2018) First Half of FY 2018 (Data reported July–December 2018)	3	0	0	0	0	3
Northeast Plume Operations and Maintenance Program *Semiannual FFA Progress Reports:* (see links above)						
Quarterly Optimization Wells	0	0	36	0	0	36
Northwest Plume Operations and Maintenance Program *Semiannual FFA Progress Reports:* (see links above)						
Semiannual Wells	0	0	32	0	0	32
Quarterly Wells	0	0	1	0	0	1
C-400 Cleaning Building Interim Remedial Action Monitoring Wells *Semiannual FFA Progress Reports:* (see links above)						
Semiannual Wells	0	0	8	0	0	8
Quarterly Wells	0	0	11	0	0	11
Former Oil Landfarm (SWMU 1) Monitoring Wells *Five-Year Review* (to be reported in 2018)						
Semiannual Wells	0	0	7	0	0	7
Water Policy Boundary Monitoring Program *Annual Site Environmental Report*						
Northwestern Wells (quarterly)	0	0	20	0	0	20
Northeastern Wells (annual)	0	0	7	0	0	7
Carbon Filter Treatment System *Annual Site Environmental Report*	0	0	1	0	0	1
Environmental Surveillance Groundwater Monitoring Program *Annual Site Environmental Report*						
Annual Wells	0	1	28	0	1	30
Semiannual Wells	0	0	3	0	0	3
Quarterly Wells	0	0	3	0	0	3

[a] Some wells are sampled under more than one program.

6.4 GROUNDWATER MONITORING RESULTS

Groundwater monitoring at the Paducah Site addresses programs including general environmental surveillance, current and inactive landfills, groundwater plume pump-and-treat operations, the C-400 Cleaning Building Interim Remedial Action monitoring, and area residential wells. The Environmental Surveillance Groundwater Monitoring Program is reviewed each year and modified as appropriate to continue to delineate the boundaries of the contaminant plumes over time. Groundwater monitoring results from all sampling efforts conducted by the Paducah Site are compiled in the Paducah Oak Ridge Environmental Information System (OREIS) database. Analytical results of interest are available upon request (by e-mailing PegasisAdmins@pad.pppo.gov) or by visiting the PEGASIS website at https://pegasis.pad.pppo.gov/ to view data. A summary of detected analytes from monitoring well groundwater samples (i.e., typically station names that begin with "MW") in 2018 are shown in Table 6.2.

The Paducah Site groundwater plume maps are used to facilitate planning to optimize the site groundwater cleanup. These maps depict the general footprint of the TCE and technetium-99 contamination in the RGA and convey the general magnitude and distribution of contamination within the plumes above the MCL. For additional description of the Paducah Site plumes, please see *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2016 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (FPDP 2017). This document is available from the Environmental Information Center (https://eic.pad.pppo.gov).

Records of decision have been put in place under the Groundwater Operable Unit for the following Projects:

- SWMU 91 (DOE 1998a);
- Northwest Plume (DOE 1993 and DOE 2010);
- Northeast Plume (DOE 1995b and DOE 2015);
- C-400 Cleaning Building source area (DOE 2005); and
- Southwest Plume (DOE 2012).

These documents can be found in the Environmental Information Center (https://eic.pad.pppo.gov). The locations of groundwater contamination sources are shown in Figure 6.3. Table 6.3 lists the cumulative TCE removed from liquid VOCs and VOCs on carbon recovered through CY 2018. The graphs shown in Figures 6.4 and 6.5 illustrate the cumulative TCE removed from liquid by the Northwest Plume Groundwater Treatment System and the Northeast Plume Containment System through CY 2018.

Table 6.2. Ranges of Detected Analytes in 2018 Monitoring Well Groundwater Samples

Analyte	Range
Volatile Organic Compounds	
1,1,1-Trichloroethane (µg/L)	1.2–1.2
1,1,2-Trichloroethane (µg/L)	0.34–1.16
1,1-Dichloroethane (µg/L)	0.42–15
1,1-Dichloroethene (µg/L)	0.36–53.5*
1,2-Dichloroethane (µg/L)	0.34–0.75
Acetone (µg/L)	1.79–8.09
Carbon tetrachloride (µg/L)	0.36–8.09
Chloroform (µg/L)	0.37–20.7
cis-1,2-Dichloroethene (µg/L)	0.34–14,900*
Tetrachloroethene (µg/L)	0.36–1.94
Toluene (µg/L)	0.46–0.46
trans-1,2-Dichloroethene (µg/L)	0.36–2.36*
Trichloroethene (µg/L)	0.35–53,200*
Vinyl chloride (µg/L)	0.36–370
Radionuclides	
Alpha activity (pCi/L)	6.52–14.1
Beta activity (pCi/L)	8.75–254
Radium-226 (pCi/L)	0.522–1.55
Technetium-99 (pCi/L)	9.62–10,300*
Thorium-230 (pCi/L)	2.15–2.8
Uranium-234 (pCi/L)	0.278–4.73
Uranium-235 (µg/L)	0.0371–0.0371
Uranium-235 (pCi/L)	0.758–3.83
Uranium-238 (µg/L)	4.08–4.08
Uranium-238 (pCi/L)	0.201–2.65
PCBs	
PCB-1242 (µg/L)	0.0335–0.375
PCB-1248 (µg/L)	0.0503–0.0788
Total PCBs (µg/L)	0.0335–0.375
Wet Chemistry Parameters	
Alkalinity (µg/L)	77,800–191,000
Chemical Oxygen Demand (µg/L)	9,590–65,200
Cyanide (µg/L)	1.81–1.81
Dissolved Solids (µg/L)	124,000–760,000
Iodide (µg/L)	168–737
Total Organic Carbon (µg/L)	420–33,300
Total Organic Halides (µg/L)	3.72–148

Analyte	Range
Anions	
Bromide (µg/L)	86.3–1,100
Chloride (µg/L)	896–115,000*
Fluoride (µg/L)	77.6–670
Nitrate as Nitrogen (µg/L)	44.7–5,670
Sulfate (µg/L)	6,340–831,000
Metals	
Aluminum (µg/L)	19.8–10,800
Arsenic (µg/L)	2.04–28.9
Barium (µg/L)	18.1–505
Beryllium (µg/L)	0.255–0.479
Boron (µg/L)	5.26–1,620
Cadmium (µg/L)	0.323–0.375
Calcium (µg/L)	6,480–207,000
Chromium (µg/L)	3.08–1,180
Cobalt (µg/L)	0.31–17.1
Copper (µg/L)	0.303–11.6
Iron (µg/L)	34.5–70,500
Lead (µg/L)	0.554–7.23
Magnesium (µg/L)	3,520–45,700
Manganese (µg/L)	1.01–12,200
Mercury (µg/L)	0.077–0.077
Molybdenum (µg/L)	0.201–7.79
Nickel (µg/L)	0.606–316
Potassium (µg/L)	134–34,600
Selenium (µg/L)	2.01–2.98
Silver (µg/L)	0.308–1.24
Sodium (µg/L)	14,600–154,000
Uranium (µg/L)	0.072–5.94
Vanadium (µg/L)	3.39–16.1
Zinc (µg/L)	3.32–49.4
Arsenic, Dissolved (µg/L)	2.03–12
Barium, Dissolved (µg/L)	16.9–488
Chromium, Dissolved (µg/L)	3.2–24.4
Selenium, Dissolved (µg/L)	2.01–4.03
Uranium, Dissolved (µg/L)	0.067–6.67

*Maximum results are from C-400 Cleaning Building Interim Remedial Action monitoring wells.

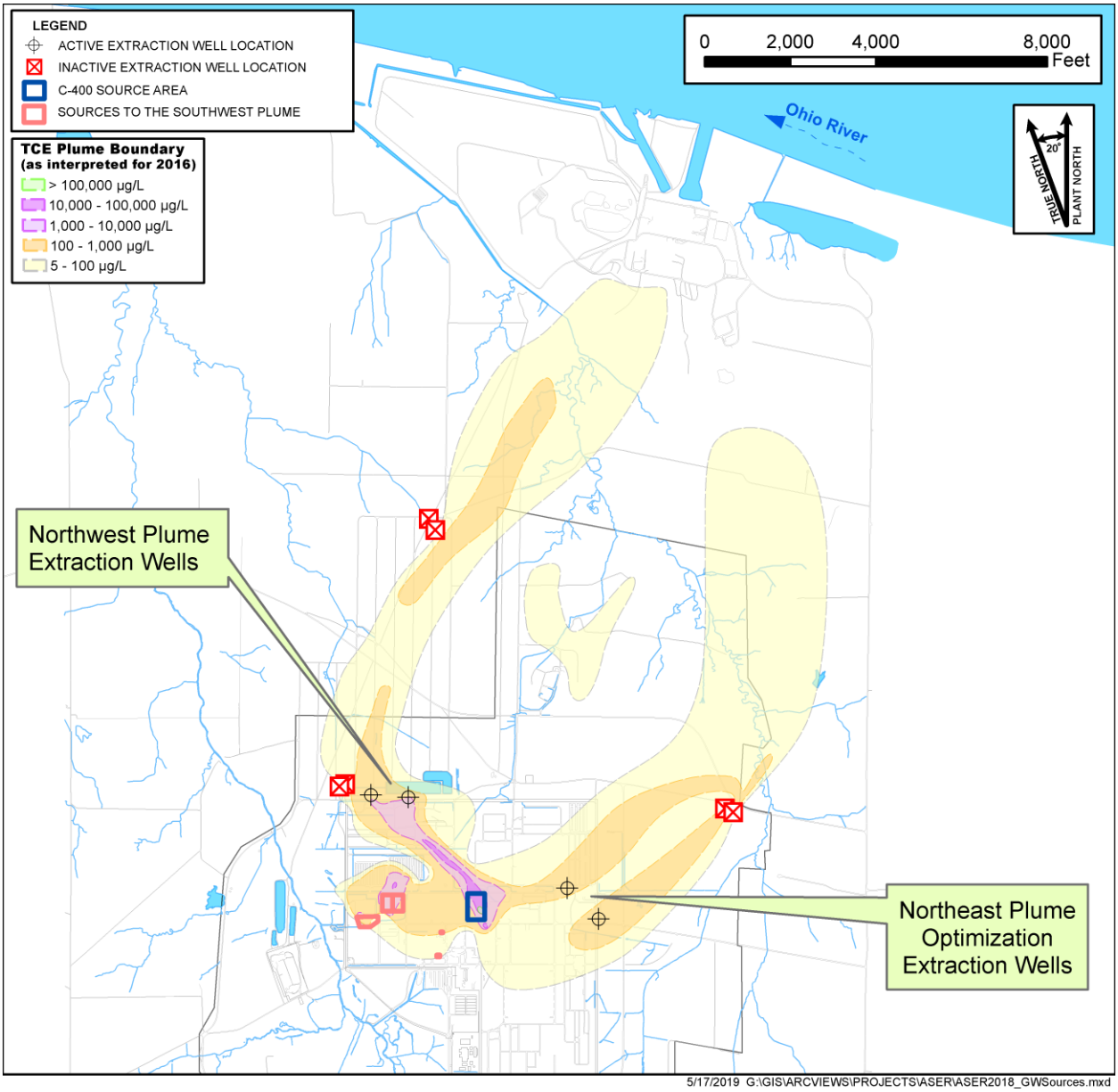
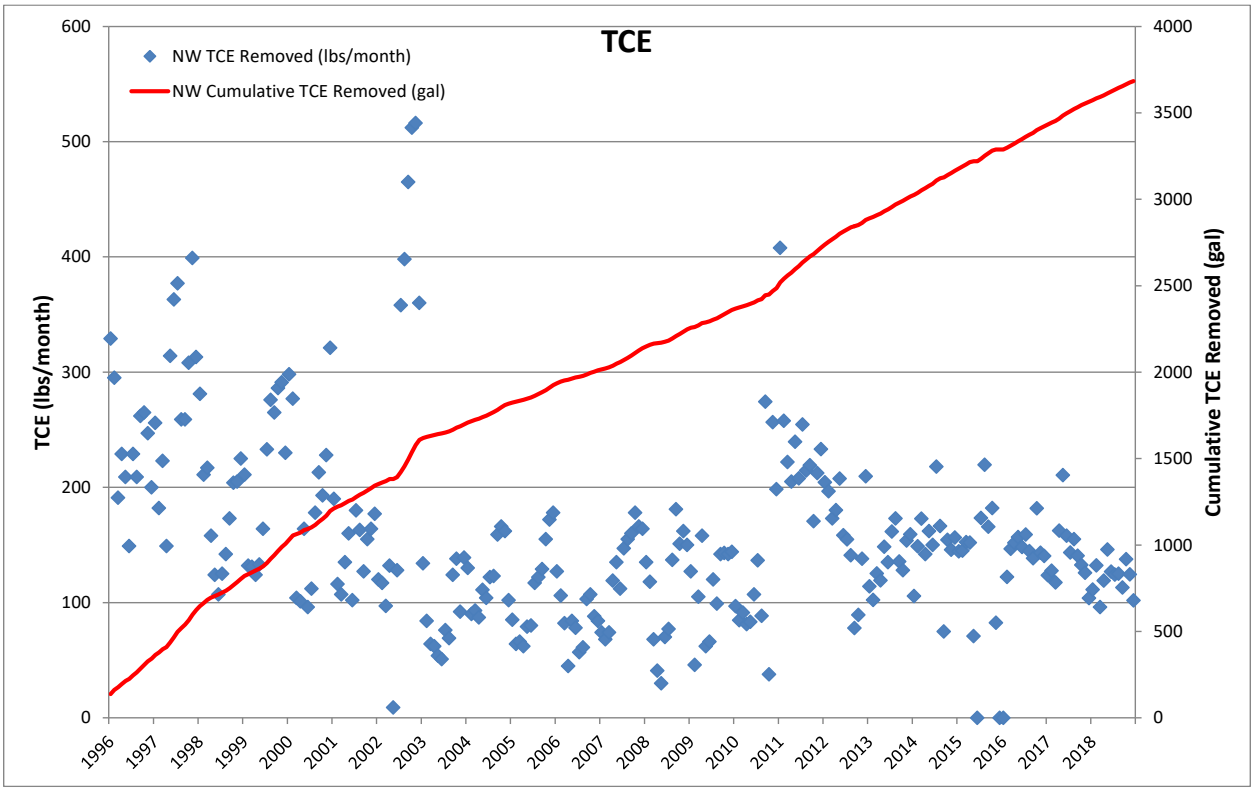


Figure 6.3. Locations of Groundwater Contamination Sources

Table 6.3. Cumulative TCE Removed at Paducah

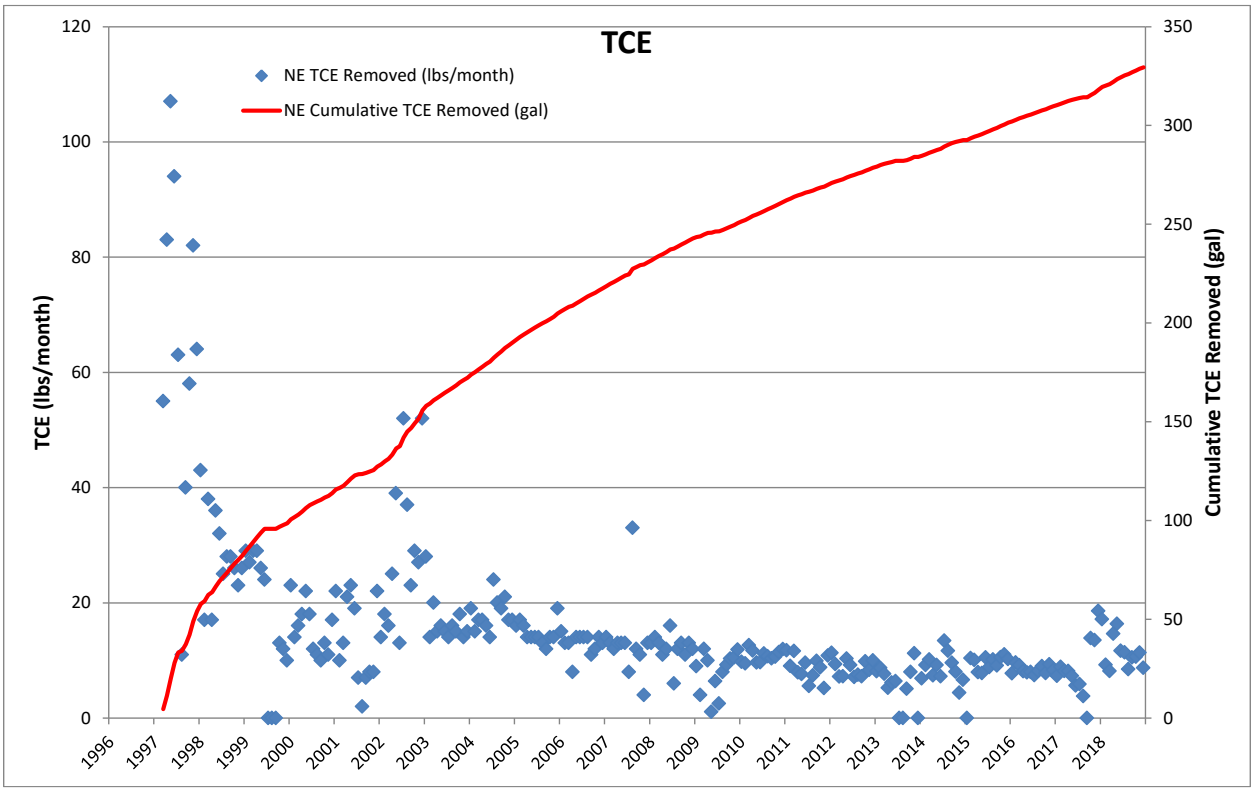
Source Area	Cumulative TCE Removed (gal) [a,b]
Northwest Plume Groundwater Treatment System	3,684
Northeast Plume Containment System	329
C-400 Cleaning Building Interim Remedial Action (including treatability study)	3,572
Southwest Plume Sources Remedial Action	24
LASAGNA™ treatment at Cylinder Drop Test Site	246

[a] TCE values include liquid VOCs and recovered VOCs on carbon.
[b] Cumulative through December 31, 2018. Value taken from DOE 2019b.



Source: DOE 2019b

Figure 6.4. Northwest Plume Groundwater Treatment System TCE Removed



Source: DOE 2019b

Figure 6.5. Northeast Plume Containment System TCE Removed

The Kentucky Solid Waste Facility (401 *KAR* 47:030 § 6) maximum contaminant level exceedances for 2018 are listed in Table 6.4.

Table 6.4. Summary of Maximum Contaminant Level Exceedances for C-746-S & -T and C-746-U in 2018

Upper Continental Recharge System	Upper RGA	Lower RGA
	C-746-S and C-746-T Landfills	
MW390: beta activity	MW369: beta activity MW372: beta activity, trichloroethene MW384: beta activity MW387: beta activity, trichloroethene MW39l: trichloroethene MW394: trichloroethene	MW370: beta activity MW373: trichloroethene MW385: beta activity MW388: beta activity MW392: trichloroethene
	C-746-U Landfill	
No exceedances	MW357: trichloroethene MW366: trichloroethene MW369: beta activity MW372: beta activity, trichloroethene	MW358: beta activity, trichloroethene MW361: trichloroethene MW364: trichloroethene MW367: trichloroethene MW370: beta activity MW373: trichloroethene

Shading indicates a background monitoring well.

A Groundwater Assessment Report documented that there was no evidence indicating a release from the C-746-U Landfill (LATA Kentucky 2013). The data used to support this assessment were groundwater analyses of quarterly and semiannual monitoring for the period 2002 through 2012 and the focused sampling of October 2006. The report found that the beta activity (associated with technetium-99) and TCE in the wells are not landfill-related, but originate upgradient of the C-746-S, C-746-T, and C-746-U Landfills.

Statistical analyses also are used to evaluate compliance monitoring wells at the C-746-S and C-746-T Landfill, the C-746-U Landfill, and the C-404 Landfill. Each report lists any statistical exceedance that is found. Reports for each landfill are listed in Table 6.1.

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7. QUALITY ASSURANCE

The Paducah Site maintains a QA/Quality Control (QC) Program to verify the integrity of data generated within the Environmental Monitoring Program. Each aspect of the monitoring program, from sample collection to data reporting, must comply with quality requirements and assessment standards. Requirements and guidelines for the QA/QC Program at the Paducah Site are established by the following:

- DOE Order 414.1D, *Quality Assurance*;
- Environmental Management Quality Assurance Program, EM-QA-001, Rev 1;
- *Quality Assurance Program Description at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, CP2-QA-1000, Rev.1;
- Commonwealth of Kentucky and federal regulations and guidance from EPA;
- American National Standards Institute;
- American Society of Mechanical Engineers;
- American Society for Testing and Materials; and
- American Society for Quality Control.

The QA/QC Program specifies organizational and programmatic elements to control equipment, design, documents, data, nonconformances, and records. Emphasis is placed on planning, implementing, and assessing activities and implementing effective corrective actions, as necessary. Program requirements are specified in project and subcontract documents to ensure that requirements are included in project-specific QA plans and other planning documents. The Paducah Site uses laboratories audited through the DOE Consolidated Audit Program. The DOE Consolidated Audit Program (DOECAP) implements annual performance qualification audits of environmental analytical laboratories and commercial waste treatment, storage, and disposal facilities to support complex-wide DOE mission activities.

In 2018, the *Environmental Monitoring Quality Assurance Project Plan* (QA Plan) defined the relationship of each element of the Environmental Monitoring Program to key quality and data management requirements. The QA Plan is an appendix to the Environmental Monitoring Plan (FRNP 2018a).

The Paducah Programmatic Quality Assurance Project Plan was implemented in 2013 and was updated in 2018 (DOE 2018n). This plan is based on the Uniform Federal Policy for Quality Assurance Project Plans. Additionally, the following procedures further ensure quality:

- Field forms are maintained in accordance with CP3-RD-0010, *Records Management Process*.
- Communication and documentation between the sample management office and field sampling personnel are conducted in accordance with CP4-ES-5007, *Data Management Coordination*.
- Sample labels and chains-of-custody are completed according to CP4-ES-2708, *Chain-of-Custody Forms, Field Sample Logs, Sample Labels, and Custody Seals*.

- Data assessment is conducted by a technical reviewer or their designee according to CP3-ES-5003, *Quality Assured Data*.

- Logbooks and data forms are prepared in accordance with CP4-ES-2700, *Logbooks and Data Forms*.

The QA Plan and the procedures cited above were in effect and covered data collected during the time frame of January through December 2018. Additional subjects included in the QA Plan are training requirements, sample custody, procedures, and instrument calibration and maintenance.

7.1 FIELD SAMPLING QUALITY CONTROL

7.1.1 Data Quality Objectives and Sample Planning

From the start of any sampling program, data quality objectives play an important role in setting the number of samples, location of sampling sites, sampling methods, sampling schedules, and coordination of sampling and analytical resources to meet critical completion times. These sampling program criteria are documented in the Paducah Site Environmental Monitoring Plan (FRNP 2018a). The Paducah Site Environmental Monitoring Plan is evaluated and modified, as appropriate, using the data quality objectives methodology on a FY basis (i.e., October 1 through September 30) following EPA data quality objectives guidance (EPA QA/G-4).

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

7.1.2 Field Measurements

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

7.1.3 Sampling Procedures

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

7.1.4 Field Quality Control Samples

The QC program for both groundwater and environmental monitoring activities specifies a minimum target rate of 5%, or 1 per 20 environmental samples, for field QC samples. Table 7.1 shows the types of field QC samples collected and analyzed. Analytical results of field QC samples are evaluated to determine if the sampling activities biased the sample results.

Table 7.1. Types of QC Samples

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

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

7.2 ANALYTICAL LABORATORY QUALITY CONTROL

7.2.1 Analytical Procedures

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

7.2.2 Laboratory Quality Control Samples

Laboratory QC samples are prepared and analyzed as required by the analytical methods used. Typical laboratory QC samples are identified in Table 7.1. If QC acceptance criteria are not met, then appropriate action, as denoted by the analytical method, is taken or the analytical data are qualified appropriately.

7.2.3 Independent Quality Control

The Paducah Site is required by DOE and EPA to participate in independent QC programs. The site also participates in voluntary independent programs to improve analytical QC. These programs generate data that readily are recognized as objective measures that provide participating laboratories and government agencies a periodic review of their performance. These programs are conducted by EPA, DOE, and commercial laboratories. Data that do not meet acceptable criteria are investigated and documented according to formal procedures. Although participation in certain programs is mandatory, the degree of participation is voluntary, so that each laboratory can select parameters of particular interest to that facility.

KDOW requires that each laboratory performing analyses of samples for KPDES permit compliance hold a Kentucky Wastewater Laboratory Certification. Two laboratories and the FRNP sampling organization held a Kentucky Wastewater Laboratory Certification in 2018.

Additional information about the certification can be found at https://eec.ky.gov/Environmental-Protection/Water/PermitCert/LabCert/Pages/default.aspx.

7.2.4 Laboratory Audits/Sample Management Office

Laboratories used by FRNP are participants in DOECAP. DOECAP-AP provides certification of environmental laboratories through third-party organizations. This ensures that the laboratories are in compliance with regulations, methods, and procedures. Findings are documented and addressed by the audited laboratory through corrective actions. FRNP reviews the audit reports and laboratory corrective action plans for compliance with FRNP requirements on an annual basis. If not in DOECAP, laboratories are audited by FRNP for compliance with DOECAP and approved suppliers list requirements.

The following are the analytical laboratories used by the Paducah Site in 2018.

- GEL Laboratories, LLC
- Test America
- ALS Global
- Southwest Research Institute
- EMSL Analytical
- Materials and Chemistry Laboratory
- Pace Analytical Services, LLC
- Pace Analytical National Center for Testing & Innovation

The following are the waste vendor facilities used by the Paducah Site in 2018.

- Integrated Environmental Services, Inc.
- Nuratec Project Services
- Perma-Fix
- Waste Control Specialist, LLC
- Clean Harbors, LLC
- Energy*Solutions*

7.3 DATA MANAGEMENT

7.3.1 Project Environmental Measurements System

The data generated from sampling events are stored in PEMS, a consolidated site data system for tracking and managing data. The system is used to manage field-generated data, import laboratory-generated data, input data qualifiers identified during the data review process, and transfer data to the Paducah OREIS database for reporting. PEMS uses a variety of references and code lists to ensure consistency and standardization of the data.

7.3.2 Paducah OREIS

Paducah OREIS is the database used to consolidate data generated by the Environmental Monitoring Program. Data consolidation consists of the activities necessary to prepare the evaluated data for the users. The PEMS files containing the assessed data are transferred from PEMS to Paducah OREIS for future use. The Environmental Monitoring and Sample Management Office Project Manager is responsible for notifying the project team and other data users of the available data. Data used in reports distributed to

external agencies (e.g., the quarterly landfill reports and this Annual Site Environmental Report) are obtained from Paducah OREIS and have been through the data review process. [The data review process is documented in *Data and Documents Management and Quality Assurance Plan for Paducah Environmental Management and Enrichment Facilities*, Section 8.4 (DOE 1998b)]. Environmental data loaded to Paducah OREIS have been assessed, verified, and validated (if applicable), as specified in CP3-ES-5003, *Quality Assured Data*.

7.3.3 PEGASIS

PEGASIS allows public access to environmental sampling data and site-specific geographic information system features through the Internet. PEGASIS includes analytical sample results from various environmental studies, restoration reports and supporting documents, and maps. Environmental data from Paducah OREIS is loaded into PEGASIS on a quarterly basis. PEGASIS does not contain data related to waste, deactivation, demolition, or facility characterization. Access to PEGASIS is available at https://pegasis.pad.pppo.gov/.

7.3.4 Electronic Data Deliverables

A "results only" electronic data deliverable is requested for all samples analyzed by each laboratory. The results and qualifier information from the electronic data deliverable are checked in addition to the format of all fields provided. Discrepancies are reported immediately to the laboratory so corrections can be made or new electronic data deliverables can be issued. Approximately 10% of the electronic data deliverables are checked randomly to verify that the laboratory continues to provide adequate electronic data deliverables.

7.3.5 Data Packages

A Level IV data package is requested from the laboratory when data validation is to be performed on a specific sampling event or media. All data packages received from the fixed-base laboratory are tracked, reviewed, and maintained in a secure environment. The following information is tracked: sample delivery group number, date received, receipt of any electronic data deliverable, and comments. The contents of the data package and the chain-of-custody forms are compared and discrepancies identified. Discrepancies are reported immediately to the laboratory and data validators. All data packages are forwarded electronically to the Document Management Center for permanent storage.

7.3.6 Laboratory Contractual Screening

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

7.3.7 Data Verification, Validation, and Assessment

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

Data validation is the process performed by a qualified individual for a data set, independent from sampling, laboratory, project management, or other decision making personnel. Data validation evaluates laboratory adherence to analytical method requirements. Validation qualifiers are stored in PEMS and transferred with the data to Paducah OREIS. Data from routine sampling events are validated programmatically at a frequency of 5% of the total data packages. Each of the selected data packages, which make up 5% of the total number of data packages, is validated 100%. From the environmental monitoring data, 46 packages were validated in CY 2018.

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

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GLOSSARY

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

activity—See radioactivity.

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

air stripping—The process of bubbling air through water to remove volatile organic compounds (VOCs) from the water.

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

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

analyte—A constituent or parameter being analyzed.

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

assimilate—To take up or absorb.

authorized limit—A limit on the concentration or quantity of residual radioactive material on the surfaces or within property that has been derived consistent with U.S. Department of Energy (DOE) directives including the as low as reasonably achievable (ALARA) process requirements. An authorized limit also may include conditions or measures that limit or control the disposition of property.

beta activity—A measure of the emission of beta particles during radioactive decay. Beta particles are negatively charged particles 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.

biota concentration guide (BCG)—The limiting concentration of a radionuclide in soil, sediment, or water that would not cause dose limits for protection of populations of aquatic and terrestrial biota (as used in DOE technical standard, DOE-STD-1153-2002) to be exceeded.

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

clearance of property—The removal of property that contains residual radioactive material from DOE radiological control under 10 *CFR* Part 835 and DOE Order 458.1.

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

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

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

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

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

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

contamination—Deposition of radioactive material on the surfaces of structures, areas, objects, or personnel; or introduction of microorganisms, chemicals, toxic substances, wastes, or wastewater into water, air, and soil in a concentration greater than that found naturally.

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 used commonly:

- **kilocurie (kCi)**—10^{3} Ci, one thousand curies; 3.7×10^{13} disintegrations per second.
- **millicurie (mCi)**—10^{-3} Ci, one-thousandth of a curie; 3.7×10^{7} disintegrations per second.
- **microcurie (µCi)**—10^{-6} Ci, one-millionth of a curie; 3.7×10^{4} disintegrations per second.
- **picocurie (pCi)**—10^{-12} Ci, one-trillionth of a curie; 3.7×10^{-2} disintegrations per second.

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

dense nonaqueous-phase liquid—The liquid phase of chlorinated organic solvents. These liquids are denser than water and include commonly used industrial compounds such as tetrachloroethene and trichloroethene.

detected value—The value reported by the laboratory for an analysis that the laboratory or a third-party data validator does not qualify with a "U" or "<."

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

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

- **absorbed dose**—The quantity of radiation energy absorbed by an organ divided by the organ's mass. Absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 Gy).

- **dose equivalent**—The product of the absorbed dose (rad) in tissue and a quality factor. Dose equivalent is expressed in units of rem (or sievert) (1 rem = 0.01 Sv).

- **committed dose equivalent**—The calculated total dose equivalent to a tissue or organ over a 50-year period after known intake of a radionuclide into the body. Contributions from external dose are not included. Committed dose equivalent is expressed in units of rem (or sievert).

- **committed effective dose equivalent/committed effective dose**—The sum of total absorbed dose (measured in mrem) to a tissue or organ received over a 50-year period resulting from the intake of radionuclides, multiplied by the appropriate weighting factor. The committed effective dose equivalent is the product of the annual intake (pCi) and the dose conversion factor for each radionuclide (mrem/pCi). Committed effective dose equivalent is expressed in units of rem (or sievert).

- **effective dose equivalent/effective dose**—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 effective dose equivalent/collective dose equivalent**—The sums of the dose equivalents or effective dose equivalents of all individuals in an exposed population within a 50-mile radius expressed in units of person-rem (or person-sievert). When the collective dose equivalent of interest is for a specific organ, the units would be organ-rem (or organ-sievert). The 50-mile distance is measured from a point located centrally with respect to major facilities or DOE program activities.

downgradient—In the direction of decreasing hydrostatic head.

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

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

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

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

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

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.

groundwater, unconfined—Water that is in direct contact with the atmosphere through open spaces in permeable material.

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

hardness—The amount of dissolved calcium and magnesium in water.

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

hydrogeology—Hydraulic aspects of site geology.

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

internal exposure—Occurs when natural radionuclides enter the body by ingestion of foods or liquids or by inhalation. Radon is the major contributor to the annual dose equivalent for internal radionuclides.

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

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

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

laboratory 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.

limited area—The industrial area at the Paducah Site, comprising approximately 644 acres.

low-level waste—Low-level waste is radioactive waste that is not high-level waste; spent nuclear fuel; transuranic waste; byproduct material (as defined in Section 11e.(2) of the *Atomic Energy Act of 1954*, as amended); or naturally occurring radioactive material.

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.

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

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

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

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

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

personal property—Property of any kind, except for real property.

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

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

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

process water—Water used within a system process.

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

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

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

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

radioactivity—The spontaneous discharge of radiation from atomic nuclei. This is usually in the form of beta or alpha radiation, together with gamma radiation. Beta or alpha emission results in transformation of the atom into a different element, changing the atomic number by +1 or -2 respectively.

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.

real property—Land and anything permanently affixed to the land such as buildings, fences, and those things attached to the buildings, such as light fixtures, plumbing, and heating fixtures, or other such items, that would be personal property, if not attached.

record of decision—A public document that explains which cleanup alternatives will be used to clean up a Superfund site.

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

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

remediation—The correction of a problem. See Environmental Restoration.

reportable quantity—An amount set by a regulation in which release to the environment must be reported to regulatory agencies.

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

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

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

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.

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

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

terrestrial radiation—Ionizing radiation emitted from radioactive materials, primarily K-40, thorium, and uranium, in the earth's soils. Terrestrial radiation contributes to natural background radiation.

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

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

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

upgradient—In the direction of increasing hydrostatic head.

volatile organic compound (VOC)—Any organic compound that has a low boiling point and readily volatilizes into air (e.g., trichloroethane, tetrachloroethene, and trichloroethene).

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

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