2017 Paducah Site
Annual Site Environmental Report

FRNP-RPT-0022

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-0022

Paducah Site
Annual Site Environmental Report
for Calendar Year 2017

September 2018

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

ALARA	as low as reasonably achievable
BCG	biota concentration guide
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	DOE Consolidated Audit Program
DUF_6	depleted uranium hexafluoride
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ERPP	Environmental Radiation Protection Program
FFA	Federal Facility Agreement
FFS	Fluor Federal Services, Inc.
FR	*Federal Register*
FRNP	Four Rivers Nuclear Partnership, LLC
FY	fiscal year
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
NRC	Nuclear Regulatory Commission
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
SST	Swift & Staley Inc.
SWMU	solid waste management unit
TLD	thermoluminescent dosimeter
USEC	United States Enrichment Corporation
VOC	volatile organic compound
WKWMA	West Kentucky Wildlife Management Area

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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 2017* 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 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 purpose of this Annual Site Environmental Report is to summarize calendar year 2017 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 2017 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 4.1 mrem/year, or less than 1/20 of the acceptable 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 2017 include the following: removed approximately 150 gal of trichloroethene from contaminant source areas at Paducah; continued to optimize the Paducah Site's infrastructure to conserve energy/water and reduce utility costs; converted approximately 6,318 metric tons of depleted uranium hexafluoride to a more stable oxide and hydrofluoric acid; and reused or recycled materials, including over 5 tons of used electronics.

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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) 2017 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 PGDP, 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 environmental regulations. The current environmental strategy is to prevent noncompliance, to identify any current compliance issues, and to develop a system for resolution. The long-range goal of DOE Environmental Management is to control and reduce 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). In February 2017, MCS succeeded BWX Technologies, Inc., for the operation of depleted uranium hexafluoride (DUF_6) conversion facilities at Paducah, Kentucky, and Portsmouth, Ohio. In October 2017, FRNP replaced Fluor Federal Services, Inc., (FFS) for deactivation and remediation services.

1.1 SITE LOCATION

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). Until 2013, the Paducah Site was an active uranium enrichment facility with extensive support facilities. The uranium enrichment process was housed in several large buildings.

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

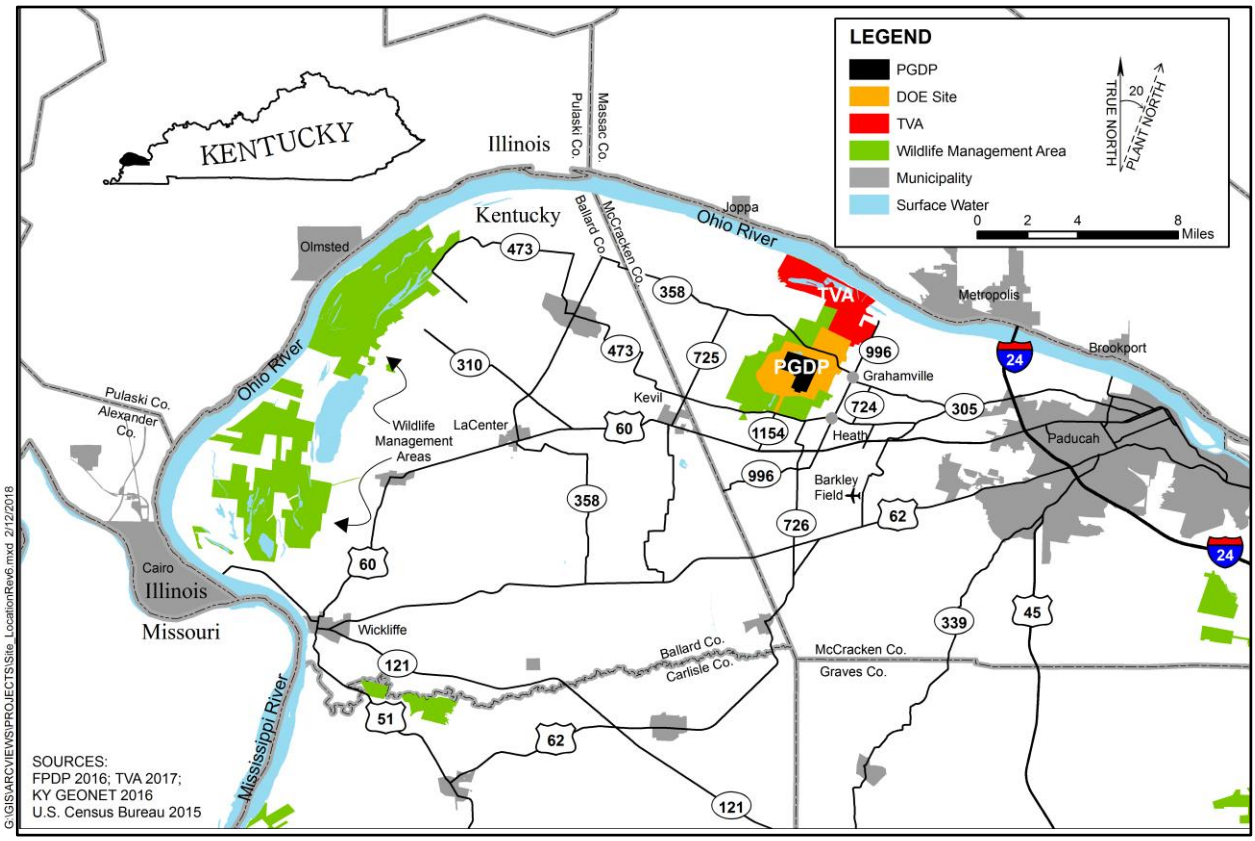

Figure 1.1. Location of the Paducah Site

The plant is on a 3,556-acre DOE site comprised of the following: approximately 628 acres are within a fenced security area, approximately 809 acres are located outside the security fence, 133 acres are in acquired easements, and the remaining 1,986 acres 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 a considerable number of 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 Energy Policy Act of 1992 transferred operational responsibility for the uranium enrichment enterprise to the United States Enrichment Corporation (USEC), a government corporation that became a publicly held company in 1998. In accordance with the Energy Policy Act of 1992, USEC assumed responsibility on July 1, 1993, for enrichment operations and leased the real property, facilities, and infrastructure necessary for enrichment operations from DOE. Until 2013, USEC enriched uranium at the Paducah Site to supply nuclear fuel to electric utilities worldwide. In 2014, USEC returned Paducah leased facilities to DOE control, and the DOE Deactivation and Remediation Contractor began management of the facilities for DOE. These returned facilities are undergoing deactivation in preparation for decommissioning. Deactivation and remediation work continued in 2017.

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.

During August 2017, the Paducah Site was within the path of totality for the solar eclipse. Figure 1.2 is a picture from the event.[2]

Figure 1.2. 2017 Solar Eclipse

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

[2] All pictures within this document are the property of DOE.

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 2017, 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 2017a).

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 14 species of federal concern exists in the study area. Twelve 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 PPPO’s goal is to accelerate the site cleanup at the Portsmouth and Paducah gaseous

diffusion plants, eliminating potential environmental threats, reducing the DOE footprint at each of the sites, and reducing life-cycle cost.

In addition to gaseous diffusion plant stabilization, deactivation, and infrastructure optimization, 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
- DUF_6 Conversion
- Decontamination and Decommissioning

1.4 PRIMARY OPERATIONS AND ACTIVITIES AT THE PADUCAH SITE

Figure 1.3. DOE Paducah Site at Sunrise

The following two major programs are operated by DOE at the Paducah Site: (1) Environmental Management and (2) Uranium Program. Environmental Restoration; Facility Stabilization, Deactivation, and Infrastructure Optimization; and Waste Management are projects under the Environmental Management Program. The Paducah Site is shown in Figure 1.3. The mission of the Environmental Restoration Project is to ensure that releases from past operations at the Paducah Site are investigated and that appropriate response action is taken for protection of human health and the environment in accordance with the Federal Facility Agreement (FFA) (EPA 1998). The mission of 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 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 the conversion of DUF_6 to a more stable oxide and hydrofluoric acid, and to manage associated facilities and grounds. The environmental monitoring summarized in this report supports DOE programs/projects. Additional information regarding these activities is found in Section 3.1.

1.5 DEMOGRAPHIC INFORMATION

The population of McCracken County, Kentucky, is approximately 65,000 (DOC 2018). The major city in McCracken County is Paducah, Kentucky, whose population is approximately 25,000 (DOC 2018). 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.

2. COMPLIANCE SUMMARY

Principal regulating agencies are the U.S. Environmental Protection Agency (EPA), Region 4, and the Kentucky Department for Environmental Protection (KDEP). These agencies issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and oversee compliance with applicable laws and regulations.

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

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 the Comprehensive Environmental Response, Compensation, and Liability Act (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 requires that DOE submit an annual Site Management Plan that summarizes remediation work completed to date, outlines remedial priorities, and contains schedules for completing future work. The fiscal year (FY) 2015 Site Management Plan was approved in April 2015 and May 2015 by KDEP and EPA, respectively (DOE 2015a). The FFA parties agreed to suspend efforts to finalize the FY 2016 Site Management Plan in consideration of the FFA parties' current efforts to integrate elements of DOE's sitewide cleanup plan. FY 2017 and FY 2018 Site Management Plans have been submitted to EPA and KDEP for review and approval.

Significant milestones required under CERCLA and the FFA for CY 2017 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.

Table 2.1. CERCLA FFA Significant Milestones Completed in CY 2017

Document/Activity	Date Due	Date Completed
Burial Grounds Operable Unit Solid Waste Management Unit (SWMU) 4 Feasibility Study D1	4/22/2017	4/21/2017
Site Management Plan for FY 2018 D1	11/15/2017	11/15/2017
Northeast Plume Optimization fieldwork		CY 2017
Burial Ground Operable Unit for SWMUs 2, 3, 7, and 30 Feasibility Study D2/R1 (dispute resolution requirement)		

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). In 2016, the C-733 Waste Oil and Chemical Storage Facility was partially closed by removing four 3,000-gal tanks. 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. In March 2016, DOE revised the Hazardous Waste Facility Permit Application to address EPA feedback concerning applicability of RCRA air emission standards. EPA currently is evaluating the revised application. Pending issuance of the renewal for the Hazardous and Solid Waste Amendments Permit, the Paducah Site continues operating in compliance with the existing Hazardous and Solid Waste Amendments Permit issued on April 24, 2006, in accordance with 40 *CFR* § 270.51(a). For CY 2017, there were no notices of violation (NOVs) issued for the hazardous waste facility permit or Hazardous and Solid Waste Amendments Permit (KY8-890-008-982).

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 mixed chemical 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, 2017, no addition of mixed low-level waste was added to the Site Treatment Plan (DOE 2018a).

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 PGDP projects 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;
- Treating wastewaters on-site to meet discharge limitations;
- 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 PGDP 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.

The PPPO began drafting 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.[3]

A categorical exclusion was approved for demolition of support buildings. Numerous minor activities conducted in 2017, 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

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

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 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 Toxic Substances Control Act Uranium Enrichment Federal Facilities Compliance Agreement. The Toxic Substances Control Act Uranium Enrichment Federal Facilities Compliance Act Agreement 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. 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 2017 are documented in the Annual Compliance Agreement Report for the Paducah Gaseous Diffusion Plant (PGDP 2017a) and the PCB Annual Document (FRNP 2018b).

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.* Under these orders, DOE establishes the requirements for protection of the public and the environment against any undue risk from radiation associated with radiological activities at DOE sites and ensures radioactive waste is managed in a manner that is protective of worker and public health, safety, and the environment. Authorized Limits have been approved for the C-746-U Landfill and for DOE-owned property outside the Limited Area. 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 shipping low-level waste to Waste Control Specialists, LLC,

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.

RCRA Landfill; and for disposal of waste containing residual radioactive materials at the Energy*Solutions* Carter Valley Landfill, Tennessee.

These limits implement DOE Order 458.1 and ensure that doses to the public meet DOE standards and are as low as reasonably achievable (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, FRNP implements an Environmental Radiation Protection Program (ERPP) (FRNP 2017). 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, high-level, and transuranic waste 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. Air emissions at the Paducah Site fall under one of three authorities: the DUF_6 Conversion Facility Conditional Major Air Permit, the FRNP Title V Air Permit, or CERCLA.

During 2017, the DUF_6 Conversion Facility operated under KDAQ Conditional Major Operating Air Permit No. F-15-042 R1, issued on March 17, 2016.

The Conversion Building houses four parallel process lines. The operation utilizes a one-step fluidized bed process to convert DUF_6 to uranium oxide powder. This is accomplished by reacting DUF_6 gas with steam, nitrogen, and hydrogen that produces hydrofluoric acid. The oxide powder is collected and packaged for reuse or disposal, while hydrofluoric acid is a saleable end product. Low levels of hydrofluoric acid off-gassed from the conversion process (hydrogen fluoride vapor) are captured by a primary and secondary caustic scrubber system. Emissions from oxide handling are controlled by a high-efficiency particulate air filter system. Air that is displaced during filling and emptying of hydrofluoric acid storage tanks at the hydrofluoric acid storage and load-out area is vented through a dedicated scrubber system. The facility has two emission points. Emission point U001 is the stack for the Conversion Building. Emission point U002 is the stack for hydrofluoric acid storage and load-out area.

Any stationary source with the potential to emit more than 100 tons per year of any regulated air pollutant other than a hazardous air pollutant, 10 tons per year of any hazardous air pollutant, or 25 tons per year of any combination of hazardous air pollutants is considered a major source under Title V of the Clean Air Act. Title V major sources are subject to Title V permitting requirements. FRNP currently operates under the Title V permit V-14-012 R3, issued on October 20, 2017, from KDAQ. Previously, FFS operated under Title V permit V-14-012 R1 from January 1, 2017, through August 30, 2017, and Title V permit V-14-012 R2 from August 31, 2017, through October 19, 2017.

CERCLA response actions also were a source of air pollutants in 2017. These sources include the Northwest Plume Groundwater Treatment System, the Northeast Plume Containment System Alternate Treatment Unit, and the Southwest Plume Sources Remedial Action. These systems are interim remedial actions under CERCLA that address the containment of groundwater contamination at the Paducah Site. 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. These systems remove trichloroethene (TCE) and other volatile organic compound (VOC) contamination from the groundwater by air stripping. At the Northwest Plume Groundwater Treatment System, the VOC-contaminated groundwater passes through an air stripper to remove the TCE. The off-gas from the air stripper then passes through a carbon adsorption system to remove the TCE prior to atmospheric discharge. At the Northeast Plume Containment System, the system includes pretreatment filtration and removal of TCE via air stripping technology. Concentrations of TCE in the Northeast Plume are sufficiently low that a carbon adsorption system is not required to keep emissions below regulatory threshold levels.

For CY 2017, DOE did not receive any NOVs under the Clean Air Act.

2.3.2 National Emission Standards for Hazardous Air Pollutants Program

Airborne emission of radionuclides from DOE facilities 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 EPA-approved NESHAP Management Plan for Emission of radionuclides (LATA Kentucky 2013a). Potential radionuclide sources at the Paducah Site in 2017 were from deactivation of PGDP, DUF_6 Conversion Facility, Northeast Plume Containment System, 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 off-site 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.

2.3.3 Pollutants and Sources Subject to Regulation

The Deactivation Project is considered a major source because it has identified potential emissions of carbon monoxide, nitrogen oxides, and sulfur oxides greater than 100 tons per year, as well as potential emission of hydrogen fluoride, a hazardous air pollutant, in excess of 10 tons per year. Potential emissions of carbon monoxide, sulfur oxides and nitrogen oxides are related primarily to coal-fired boilers that were replaced in 2015 by a combination of five natural gas and natural gas/fuel-oil-fired boilers. Without potential emissions from the coal-fired boilers, which no longer are operational, the Deactivation Project still has the potential to emit more than 10 tons per year of hydrogen fluoride, with potential emissions being primarily related to cascade operations associated with deactivation activities.

KDAQ considers the DUF_6 facility to be a separate source from the Deactivation and Remediation Project and, therefore, has issued DUF_6 a separate permit. The DUF_6 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 (in Kentucky, a conditional major source is a source whose potential emissions exceed a Title V major source threshold, but which accepts permit conditions that are legally and practically enforceable to limit the source's potential to emit below major source thresholds).

2.3.4 Stratospheric Ozone Protection

DOE operates several refrigeration units that contain less than 50 pounds of ozone-depleting substances. The Paducah Site also has a very large R-114 cooling system. This system currently holds approximately 6.3 million pounds of R-114 refrigerant. Releases from the system are tracked and the sources of releases repaired in accordance with 40 *CFR* Part 82 requirements and the Title V Permit. In addition to the 6.3 million pounds of R-114 refrigerant in the cooling systems, approximately 2.2 million pounds of R-114 is stored in railcars at the Paducah Site. In 2015, FFS moved some R-114 from the cooling system into railcars and began procurement of containers to store more R-114. DOE is evaluating disposition of R-114.

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,[4] 019, and 020 (Figure 2.1). 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 and work control.

Figure 2.1. KPDES Outfall K017

During 2017, the site continued sampling and investigation efforts under a KDOW-approved Toxicity Reduction Evaluation Plan due to historical acute toxicity failures at Outfall 020, which is leachate effluent from the C-746-U Landfill leachate treatment system. After January 5, 2017, all leachate from the C-746-U Landfill was treated and discharged at the C-615 Sewage Treatment Plant, while toxicity reduction efforts continued throughout the remainder of 2017.

Three NOVs were received during CY 2017 related to the KPDES permits. The first NOV received was in March of 2017 and the NOV was for an exceedance of carbonaceous biochemical oxygen demand for discharged water from the water treatment plant at Outfall 004. Carbonaceous biochemical oxygen demand measures the availability of oxygen in water. The discharged water is sampled twice per month as required by the KPDES permit. The exceedance is attributed to operational issues associated with the trickling filter, which functions to distribute water over a filter bed as part of the water treatment process. Maintenance actions were taken immediately after the sample results were obtained and the second sample collected in the month of March 2017 was in compliance with the KPDES permit. The two other NOVs received during 2017 were for chronic toxicity exceedances at Outfall 017 during the months of May and June 2017. Chronic toxicity is a measurement of the characteristics of water discharged from an outfall that could be harmful to aquatic organisms. Outfall 017 is discharged effluent associated with the facility that processes depleted uranium hexafluoride. The chronic toxicity limit at Outfall 017 is 1.0 Chronic Toxicity Units. The initial May 2017 sample result was 8.0 Chronic Toxicity Units. A second sample collected in May 2017 that is required by KPDES permit was less than 1.0 Chronic Toxicity Units. In June 2017, an initial sample of 1.09 Chronic Toxicity Units exceeded the permit limit. A second sample required by the KPDES permit was less than 1.0 Chronic Toxicity Units. All results were reported to KDOW, as required by the KPDES permit, and no further action was required by KDOW. Additional information is provided in Table 2.2.

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. The audit covers building envelope, lighting, possible deployment of occupancy sensors, and leaking or old water fixtures. The findings of these audits are addressed immediately. A list of previous audits is presented in the Site Sustainability Plan (SST 2016).

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

Table 2.2. KPDES Notices of Violation in CY 2017

Permit Type	Outfall	Parameter	Number of Permit Exceedances	Number of Samples Taken	Number of Compliant Samples	Percent Compliance	Month of Exceedance	
KPDES (KY0102083)	004	Carbonaceous biochemical oxygen demand	1	23	22	96%	March	
KPDES (KY0004049)	017	Chronic Toxicity	2	21	19	90%	May, June	

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 FFS, followed by FRNP, in accordance with the Safe Drinking Water Act regulations for CY 2017. 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. Remote facilities use bottled water.

FRNP operates a non-transient non-community water system, regulated by KDOW, using lime softening, coagulation, sedimentation, filtering, and disinfection for water treatment. KDOW's requirement for surface water systems serving populations less than 10,000 to submit monitoring plans to demonstrate compliance with regulations is applicable to the FRNP non-transient non-community water system. Various sampling locations in the FRNP treatment and distribution system are monitored in accordance with these plans, and the monitoring results are submitted to KDOW.

Three total NOVs pertaining to the Safe Drinking Water Act were issued during the reporting period, although one of the three NOVs later was rescinded. A NOV was issued to FFS under the Safe Drinking Water Act in March 2017, for failing to submit an operational evaluation levels report for October–December 2016. The NOV required the issuance of a public notice detailing the failure to submit the report. The public notice was issued on October 19, 2017. A NOV was issued to FFS under the Safe Drinking Water Act in May 2017 for failing to meet the treatment technique for total organic carbon removal for March 2017. KDOW later rescinded the violation, determining that the NOV should not have been issued because the site uses alkalinity as alternate compliance criteria due to its use of softening agents as part of its treatment technique. In August 2017, a NOV was issued to FFS because the Paducah Site's public water system exceeded the maximum contaminant level for locational running annual average of total trihalomethane during April–June 2017. Total trihalomethanes are formed when chlorine or other disinfectants are used in producing safe drinking water. The reported result of 0.087 mg/L exceeded the maximum contaminant level of 0.080 mg/L. The trihalomethane concentrations were reduced by immediately taking maintenance actions. The NOV required the issuance of a public notice detailing the failure to submit the report. The public notice was issued on October 19, 2017.

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

Environmental Management System 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 14 federally listed species that have been identified as potentially occurring at or near the Paducah Site. No proposed or candidate species have been identified in the area. None of these species have been reported as sighted on the DOE Reservation, although potential summer habitat exists there for the Indiana Bat (Garland 2008). No DOE project at the Paducah Site during 2017 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
	Orangefoot Pimpleback	*Plethobasus cooperianus*	Endangered
	Pink Mucket	*Lampsilis abrupta*	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 2018).

2.5.2 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.

2.5.3 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 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.

2.5.5 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 2017.

2.5.6 Underground Storage Tanks Managed under RCRA Kentucky Underground Storage Tank Regulations

Underground storage tanks are regulated under RCRA Subtitle I (40 *CFR* Part 280) and Kentucky Underground Storage Tank regulations (401 *KAR* Chapter 42). No underground storage tanks were in service at the Paducah Site during 2017.

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 C-746-U Landfill began in 1995 and was completed in 1996. The operation permit was received from KDWM in November 1996. Disposal of waste at the landfill began in February 1997. Operating and groundwater reports for the C-746-U Landfill are submitted quarterly to KDWM.

During 2017, the office waste generated by DOE and its contractors at the plant site was taken off-site for disposal. Office waste generated at the C-746-U Landfill itself is disposed of at the landfill. A commercial waste company provides off-site disposal services of the office waste from the Paducah Site. The City of Kevil picked up the office waste from the office complexes in Kevil, Kentucky, that housed administrative personnel who supported activities at the Paducah Site. Recycling is discussed in Section 3.1.2.

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. To address requirements in the Order, the site made a commitment to pursue the U.S. Green Building Council's Leadership in Energy and Environmental Design and incorporate Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings design in construction of future buildings. 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 March 19, 2015, the President signed Executive Order 13693, *Planning for Federal Sustainability in the Next Decade*. Executive Order 13693 requires federal agencies to establish greenhouse gas reduction targets and achieve sustainability goals to reach those targets. This executive order includes and expands upon prior executive order goals and requirements, as well as climate preparedness and resilience planning for the impacts of climate change. In support of DOE's goals to reduce greenhouse gas emissions, SST submitted a Site Sustainability Plan in December 2016 (SST 2016). For 2017, the Site Sustainability Plan was entered on the web-based DOE Sustainability Dashboard. 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 304 requires facilities to notify state emergency response commissions and local emergency planning committees of releases of hazardous substances and extremely hazardous substances when the release equals or exceeds the reportable quantity. Sections 311 and 312 of EPCRA require businesses to report the locations and quantities of chemicals stored on-site to state and local governments in order to help communities prepare to respond to chemical spills and similar emergencies (when chemicals exceed a 10,000 pound reporting threshold). 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.

In 2017, no EPCRA Section 311 notifications were sent for new chemicals at the Paducah Site. MCS manufactured hydrofluoric acid in 2017 and submitted a corresponding EPCRA 313 Report. DOE also submitted an EPCRA 313 Report for hydrofluoric acid as well as a report for chlorine used for water sanitization.

The chemicals stored by all DOE contractors in 2017 [including FFS (January–October 2017), FRNP (October–December 2017), MCS, and SST] were included in an EPCRA 312 Report. The chemicals reported were activated carbon, calcium hydroxide, biodiesel fuel, diesel fuel, gasoline, coagulant, calcium oxide, carbon dioxide, chlorine, chlorine trifluoride, dichlorotetrafluoroethane (R-114), ferric sulfate, ferrous sulfate, fluorine, hydrofluoric acid, lead acid batteries, nitric acid, cryogenic nitrogen, oil, potassium hydroxide, rock salt, sodium carbonate, sodium thiosulfate, uranium hexafluoride (UF_6), and uranium oxide. [UF_6 was reported as a courtesy, although radioactive substances are not subject to EPCRA Sections 311 and 312 (52 *FR* 38344-01).]

Table 2.4 lists the 2017 EPCRA reporting status for the Paducah Site.

Table 2.4. 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.

2.8.2 Adapting to Climate Change

Normal power usage, fleet exhaust, and process power account for the majority of greenhouse gas emitted, and efforts for reductions in these areas are being made. To date, the Paducah Site has made no local partnerships with federal agencies or local jurisdictions for collaboration for exploration of local climate change measures.

2.8.3 Additional Notice of Violation

In July 2017, FPDP received a NOV from the State of Utah regarding failure to provide the required Uniform Hazardous Waste Manifest for a container shipped to Clive, Utah, in May 2017. The contents of the container included PCB waste. The Uniform Hazardous Waste Manifest was provided to Energy*Solutions* in Clive, Utah, the following day.

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 103(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 2017.

2.10 UNPLANNED RELEASES

No unplanned releases were above any reportable quantity. All unplanned releases were below any reportable quantity. Small leaks and spills are cleaned and have no potential impacts on the environment.

2.11 SUMMARY OF PERMITS

Table 2.5 provides a summary of the Paducah Site environmental permits maintained by DOE in CY 2017.

Table 2.5. Permits Maintained by DOE for the Paducah Site for CY 2017

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

*KPDES permit KY0004049 was renewed in July 2017 with an effective date of September 1, 2017, and combined the previous KY0004049 permit with the KY0102083 permit.

3. ENVIRONMENTAL MANAGEMENT SYSTEM

The Environmental Management System 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*. The Environmental Management System for DOE's contractor, SST, was audited and found to satisfy DOE requirements. The Environmental Management System for the remaining contractor became effective in 2018.

Environmental protection programs at the Paducah Site conform to the five core elements of the International Organization for Standardization Environmental Management System ISO 14001:2004 standard through self declaration. The major elements of an effective System include policy, planning, implementation and operation, checking, and management review. Through implementation of the Environmental Management System, 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.

During 2017, DOE contractors were responsible for compliance with all applicable laws, regulations, permit commitments, and other requirements, as defined in their respective contracts. Their 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 project 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, Environmental Management System awareness training, and publications.

The Environmental Management System 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 Environmental Management System environmental stewardship scorecard for the Paducah Site in FY 2017 was green (which indicates standards for Environmental Management System implementation have been met).

DOE contractors at the Paducah Site are required to implement Environmental Management System requirements. The benefits of the Environmental Management System to the facility include (1) reduced risk to the facility mission; (2) improved fiscal efficiency and/or cost avoidance; (3) heightened knowledge of environmental programs at all levels of the organization; (4) empowerment of individuals to contribute to the improved environmental conditions at the site; and (5) integration of the environment into organizational culture and operations. Employees have actively recommended work controls to be used to protect the environment.

Within this section, the following are summarized.

- Environmental operating experience and performance measurement
    - Site sustainability plan
    - Waste minimization/pollution prevention
    - DUF_6 cylinder program
    - Environmental restoration, waste disposition, and deactivation and decommissioning
    - Emergency management
    - Facility stabilization, deactivation, and infrastructure optimization
- Accomplishments, awards, and recognition
    - Public awareness program
    - Community/educational outreach
    - Citizens Advisory Board
    - Environmental Information Center
    - Additional awards

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. FFS/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.

Environmental operating experience and performance measurement is an integral component of an Environmental Management System. This section discussed the site's progress on meeting these goals with respect to site sustainability and waste minimization/pollution prevention. Additionally, achievements and descriptions are provided for DOE programs.

3.1.1 Site Sustainability Plan

In accordance with DOE Order 436.1 and Executive Order 13693, 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.

In addition to making physical changes at the facility to increase sustainability, another objective is to increase awareness in workers and the surrounding community about sustainability opportunities through public outreach and training. Table 3.1 is adapted from the GDP FY 2018 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, the Environmental Management footprint went from 722,390 gross square footage to 8,174,722 gross square footage. Over 255 buildings, trailers, and other structures and facilities were reassigned to DOE's Environmental Management. 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. Using a graded approach, generating energy savings, as well as meeting other sustainability initiatives, is an important component of site stewardship.

Table 3.1. DOE Sustainability Goal Summary Table[5]

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, the Paducah Site increased utility consumption. Facilities not part of the FY 2008 baseline now are part of the Environmental Management mission at the Paducah Site. There was an ~22% decrease in electrical consumption from FY 2015 to FY 2017. At DUF_6, 10 automatic setback thermostats were installed to reduce energy intensity.
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 changed to 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.
Energy Management		
Reduce energy intensity by 25% by FY 2025 from an FY 2015 baseline.	Interim Target: -5% Current Performance: -70.4%	There are no plans to reduce energy intensity in goal subject buildings. Energy initiatives are acted upon as they are brought up.

[5] The Paducah Site has one goal that is not listed on this 2017 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 Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
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 Deactivation and Remediation Contractor is tasked with preparing an Energy Efficiency Plan during FY 2018. No energy and water evaluations have been conducted since FY 2016.
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.	There are currently no plans to meter all individual buildings for electricity, natural gas, steam and water. Water and electrical meters have no return on investment.
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%	Deactivation and Remediation Contractor currently is reviewing opportunities for continued optimization of the plant water systems, as well as an eventual transition to a local water district. Coupled with reductions in plant footprint, water usage will continue to decrease.
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: 64.7%	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: 0%	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. FY 2018 plans include the reduction of 30 fleet vehicles for the current Deactivation and Remediation Contractor.

Table 3.1. DOE 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 and the contractors are promoting E-85 use within plant communication mediums. During FY 2017 the site reduced petroleum consumption by 20.51%.
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.
75% of light-duty vehicle acquisitions must consist of alternative fuel vehicles.	Deactivation and Remediation = not applicable (N/A) SST = N/A MCS = N/A	Majority of site fleet consists of alternative fuel vehicles, although during FY 2017, SST acquired four DOE-owned, older, light-duty vehicles from the Deactivation and Remediation Contractor that were not alternative fuel vehicles due to their age. The vehicles replaced DOE-owned vehicles that were in various stages of disrepair.
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 budgeting constraints for installing a charging station.
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. DOE PPPO may purchase Renewable Energy Certificates in the future.
"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%	DOE PPPO may purchase Renewable Energy Certificates in the future.
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. Future construction may incorporate Guiding Principles, as appropriate.

Table 3.1. DOE Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
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.	New construction will consider incorporating Net Zero goals, as appropriate.
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. If projects arise, there will be more opportunity for involvement.
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.	An American Society of Heating, Refrigerating, and Air-Conditioning Engineers Level I-audit report (Phases I and II) of 25% of the covered Deactivation and Remediation Contractor facilities was issued in FY 2017.	No additional activities are planned because the Paducah Site currently is in deactivation.
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 acquired in FY 2017 were Electronic Product Environmental Assessment Tool-registered products, except for two televisions and one copier that were categorized as Energy Star.
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.

Table 3.1. DOE Goal Summary Table (Continued)

DOE Goal	Current Performance Status	Performance & Plans
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 2017, there was an electronic-scrap shipment of 11,262 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 five 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 PGDP, the Infrastructure Contractor offers excess reusable items to Paducah Area Community Reuse Organization. During FY 2017, the Paducah Site diverted 64.7% 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 PGDP related to the Site Treatment Plan waste minimization/pollution prevention in CY 2017 were the following (DOE 2018a):

- Regenerated 22,240 pounds of activated carbon averting disposal;
- Recycled 13,296 pounds of scrap metal from demolition of small trailers and mobile storage units;
- Recycled 982 pounds of various light bulbs; and
- Recycled 26,748 pounds of various batteries.

3.1.3 Depleted Uranium Hexafluoride Cylinder Program

A product of the uranium enrichment process, DUF_6 is a solid at ambient temperatures and is stored in large metal cylinders (Figure 3.1). At the end of 2017, the Paducah Site managed an inventory of approximately 52,063 cylinders stored in outdoor facilities, commonly referred to as cylinder storage yards. The inventory varies from time to time, as a result of DOE agreements to receive or market DUF_6.

Figure 3.1. DUF_6 Facility

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

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 that is suitable for disposal or reuse, and hydrofluoric acid sold for commercial use.

Consistent with Public Law 107-206, construction began in July 2004 and continued through 2008. Physical construction of the facility was completed in December 2008 and was fully operational in September 2011. During 2017, MCS converted approximately 6,318 metric tons of DUF_6 to a more stable oxide and hydrofluoric acid. Off-site shipment is discussed in Section 4.2.

In February 2017, MCS succeeded BWX Technologies, Inc., as DOE's DUF_6 contractor.

3.1.4 Environmental Restoration, Waste Disposition, and Decommissioning

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

The following are Paducah Site significant accomplishments in 2017.

- Resubmitted and received regulator concurrence for the *Addendum to the Soils Operable Unit Remedial Investigation Report for Solid Waste Management Unit 1 at the Paducah Gaseous Diffusions Plant, Paducah, Kentucky,* DOE/LX/07-0358&D2/R1/A2/R2 (DOE 2017b).

- Completed the Northeast Plume Optimization field work in 2017.

- Resolved dispute on Burial Grounds SWMUs 2, 3, 7, and 30; submitted and received approval of the Feasibility Study.

- Hosted an online community survey effort tailored to PGDP cleanup.

- Initiated C-400 Cleaning Building Vapor Intrusion Study (Figure 3.2).

- Received regulatory concurrence on *Addendum to the Remedial Investigation Report for the Burial Grounds Operable Unit Solid Waste Management Unit 4 at the Paducah Gaseous Diffusions Plant, Paducah, Kentucky,* DOE/LX/07-0030&D2/R1/A1/R2 (DOE 2017c), and submitted 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 2018b), which also received regulatory concurrence.

Figure 3.2. Installation of Vapor Intrusion Sampling Port

3.1.5 Emergency Management

Emergency management is a systematic, integrated effort at the Paducah Site. 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. The Joint Public Information Center provides timely and accurate information to the community during emergency situations.

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. Under contracts to DOE, emergency responses are coordinated at the Paducah Site through the Emergency Operations Center.

3.1.6 Facility Stabilization, Deactivation, and Infrastructure Optimization

PGDP was transferred from USEC to DOE on October 21, 2014. Since that time, the U.S. Nuclear Regulatory Commission (NRC) has terminated its certificate of compliance for PGDP, and the facilities now are regulated under DOE authority. Several modifications occurred that supported the transition during 2017. DOE continued to optimize the Paducah Site's infrastructure to conserve energy/water and reduce utility costs. The following are significant Paducah Site accomplishments in 2017.

- Continued deactivation of C-400 Cleaning Building (Figure 3.3). Sampling and repackaging of the trap mix containers in one of the process buildings were completed to support waste characterization for future demolition.

- Overhead electrical lines from Tennessee Valley Authority were reconfigured.

- Washing and disposition of 384 small cylinders were completed.

Figure 3.3. Deactivation of C-400 Cleaning Building

3.2 ACCOMPLISHMENTS, AWARDS, AND RECOGNITION

DOE and its contractors are committed to enhancing public awareness and community/educational outreach (Figure 3.4). 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.

Figure 3.4. Employees Participating in Heart Walk

3.2.1 Public Awareness Program

A comprehensive Community Relations and Public Participation Program exists for DOE activities at the Paducah Site (DOE 2018c). The purpose of the program is to provide the public with opportunities to become involved in decisions relating to environmental issues at the site.

DOE Environmental Management continued conducting guided public tours of its Paducah Site in 2017. Ten tours were conducted in 2017 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 2017. 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 3.5. Marshall County High School Students Learning about the Paducah Site

In a joint project between DOE and the Kentucky Research Consortium for Energy and Environment, administered by the University of Kentucky Center for Applied Energy Research, students from Marshall County High School summarized a previous year's Annual Site Environmental Report (Figure 3.5). Additional information is available at the following link: http://www.ukrcee.org/Marshall/Edu.html.

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 and members of the public to develop content.

In 2017, DOE contractors 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 3.6).

Figure 3.6. Interns Touring PGDP

Paducah PPPO Environmental Geographic Analytical Spatial Information System (PEGASIS) is continuously being updated to enhance usability and to include new features. 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. 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.

In September 2017, DOE invited area residents, business owners, and local government officials to participate in an on-line community survey. The survey was tailored to Paducah Site cleanup. It measured the effectiveness of past public information and education efforts and provided guidance for future communication with the public. The results of those surveys revealed that the majority of respondents (72%) were very knowledgeable, fairly knowledgeable, or had some basic knowledge of cleanup activities at the Paducah Site. The public responded positively to communications with DOE, EPA, and KDEP (DOE 2018c).

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 business, academia, labor, local government, environmentalists, special interest groups, and 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 citizen's 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 consist of the following:

- Paducah Site Baseline
- C-400 Complex Operable Unit
- Deactivation and Non-destructive Assay
- Environmental Monitoring/Site Operations

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, KDWM, 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 in the Barkley Centre, 115 Memorial Drive, Paducah, Kentucky.[6] 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.

3.2.5 Additional Awards

During 2017, SST and MCS received the Kentucky Governor's Safety and Health Award. SST was recognized for 507,044 hours worked without a workplace injury or illness resulting in days away from work during the previous year, and MCS also was recognized for achieving 796,234 hours during the same period.

[6] In May 2018, the Environmental Information Center moved to the Emerging Technology Center, Room 221, 5100 Alben Barkley Drive, Paducah, Kentucky.

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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 may 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 are constrained to 1 rad/day for aquatic organisms, 1 rad/day for terrestrial plants, and 0.1 rad/day for 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.

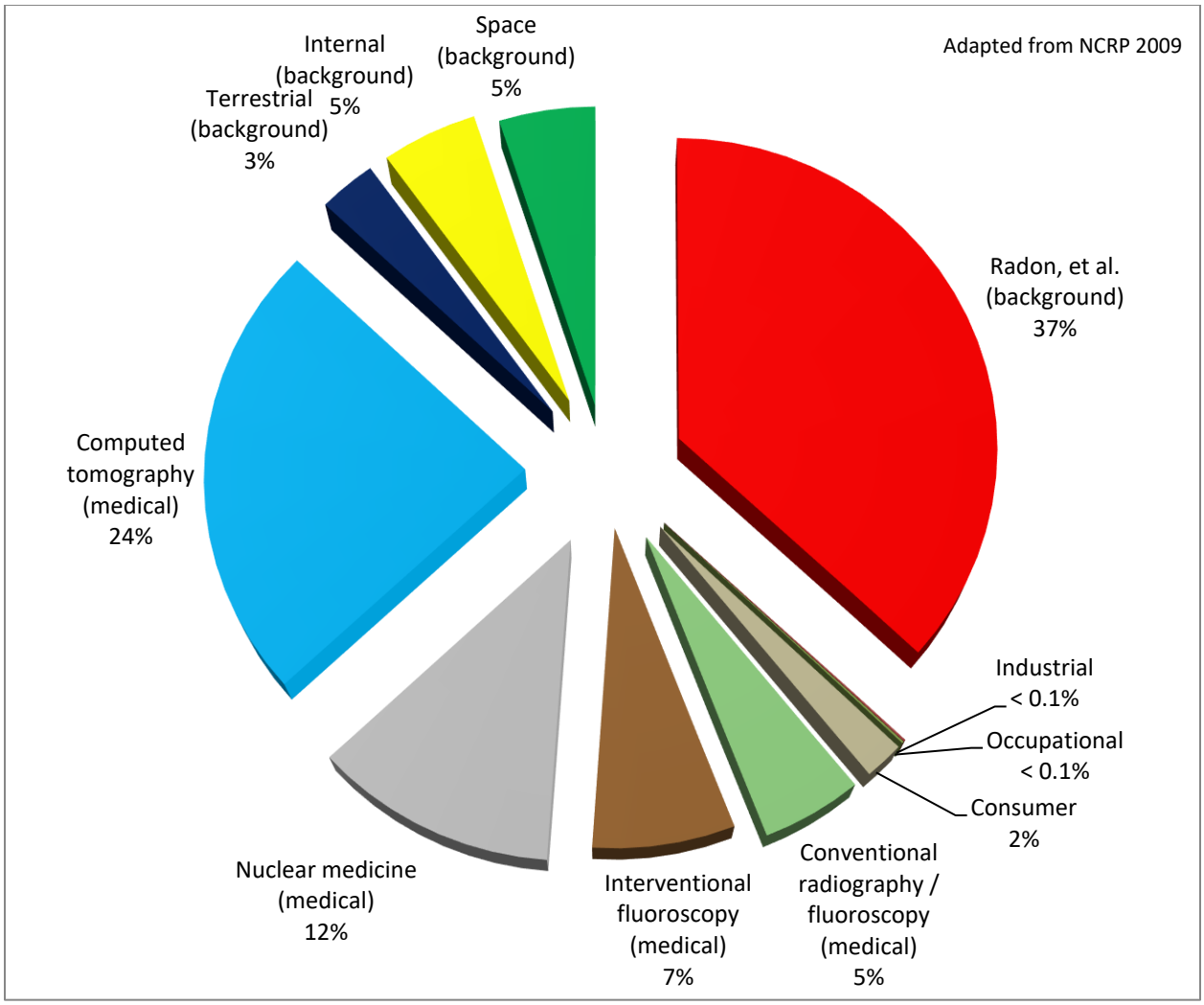

Figure 4.1. Sources of Radiation

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 (1 mSv/year) above background as the total annual dose limit to a member of the public. The established 100 mrem/year (1 mSv/year) dose limit is consistent with NRC and Kentucky Radiation Health Branch dose limits for the public. Each year, DOE operations at the Paducah Site may 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 into nuclear materials. 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 varying concentrations. 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 2017a). 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.

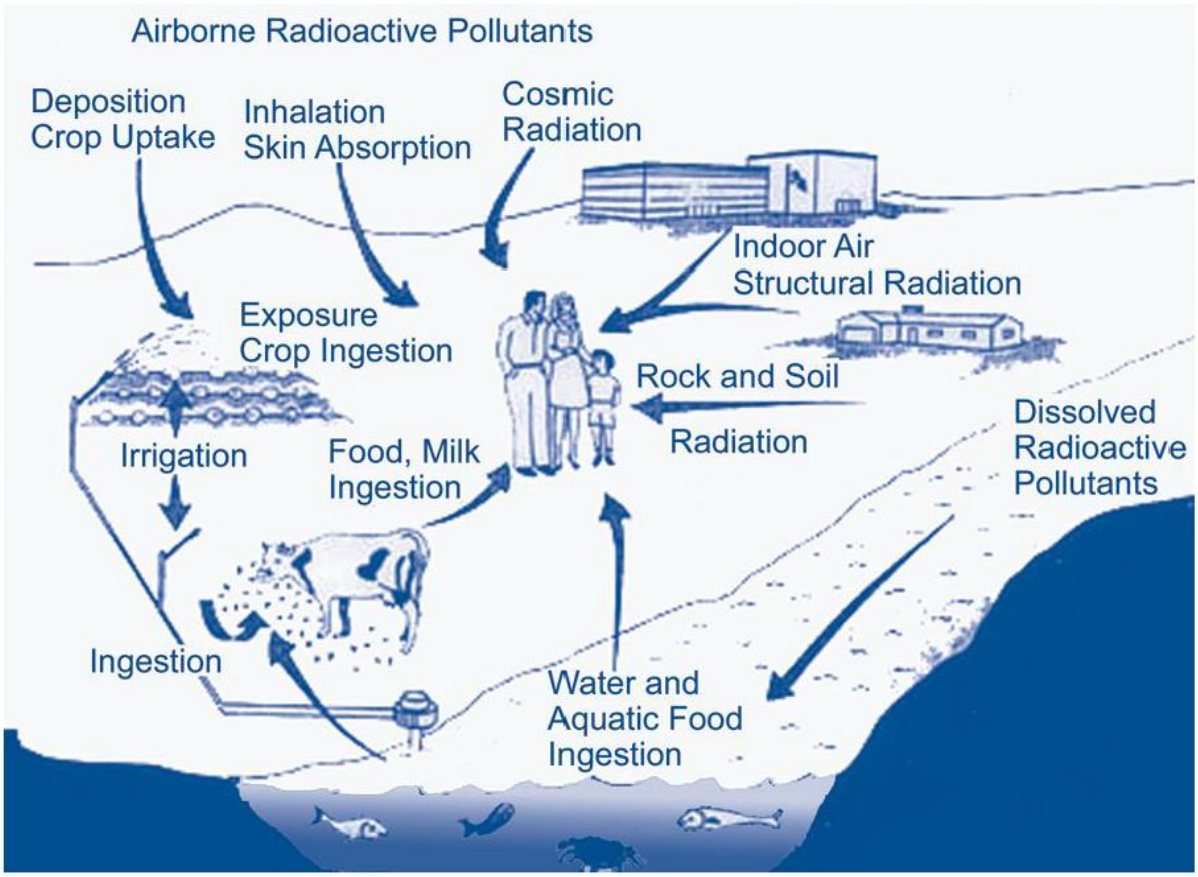

Figure 4.2. Potential Exposure Pathways

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 2017a). 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 may result in airborne releases from various sources including CERCLA remedial actions. Radionuclide sources at the Paducah Site evaluated in 2017 were the following:

- Northwest Plume Groundwater Treatment System;
- Northeast Plume Containment System Treatment Units;
- DUF_6 Conversion Facility;
- C-709/C-710 Laboratory Hoods; and
- Seal Exhaust/Wet Air Group (which includes the seal exhaust systems in the C-310 Product Withdrawal Building; C-315 Tails Withdrawal Building; C-331, C-333, C-335, and C-337 Process Buildings; wet air exhaust systems in the C-310 Product Withdrawal Building; and the C-331, C-333, C-335, and C-337 Process Buildings).

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 2017 and FY 2018 Environmental Monitoring Plans (FRNP 2018a).

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 2017 from stacks and diffuse sources on the Paducah Site (Table 4.1) were modeled using the EPA-approved Clean Air Act Assessment Package - 1988 Version 4 (CAP-88) PC computer program. This air dispersion model estimates effective dose equivalents based on the ingestion, inhalation, air immersion, and ground surface pathways. Site-specific data for CY 2017 (radionuclide releases in curies per year) were input into the CAP-88 PC program, as were on-site meteorological data.

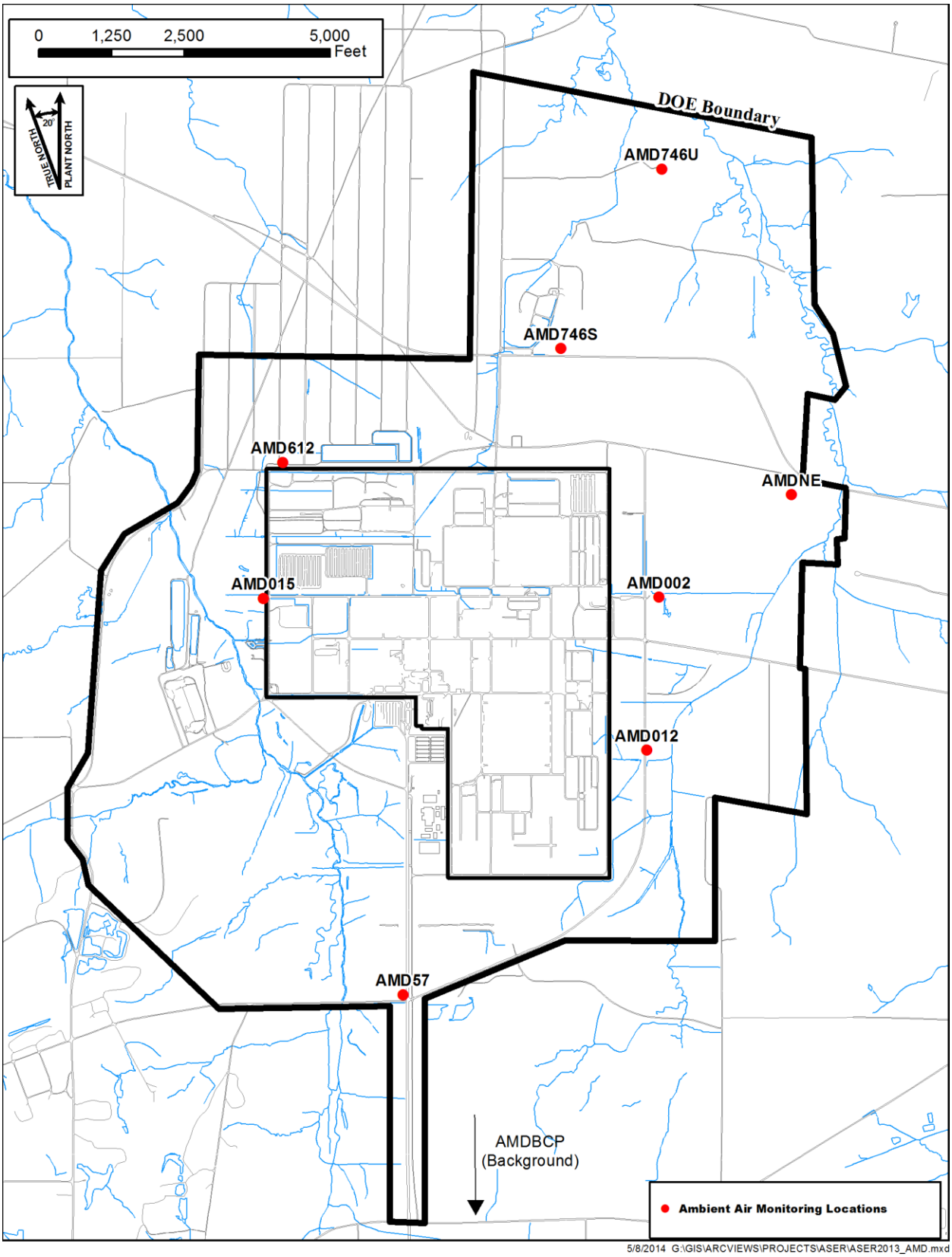

Figure 4.3. Air Monitoring Locations

Table 4.1. Radionuclide Atmospheric Releases for CY 2017 (in Curies) for the Paducah Site*

Radionuclide	Northwest Plume Groundwater Treatment System	Northeast Plume Containment System Alternate Treatment Unit SP234	Northeast Plume Containment System Alternate Treatment Unit SP235	DUF_6 Conversion Facility	C-709 & C-710	Seal Exhaust/ Wet Air Group	Total Site Emissions
Tc-99	9.53E-05	8.62E-06	2.92E-06	0.00E+00	0.00E+00	6.80E-07	1.08E-04
U-234	0.00E+00	0.00E+00	0.00E+00	9.90E-07	9.98E-04	4.18E-06	1.00E-03
U-235	0.00E+00	0.00E+00	0.00E+00	4.53E-08	3.81E-05	2.27E-07	3.84E-05
U-238	0.00E+00	0.00E+00	0.00E+00	2.43E-06	1.02E-04	1.68E-06	1.06E-04
Np-237	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Pu-239	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	5.37E-06	5.37E-06
Th-231	0.00E+00	0.00E+00	0.00E+00	3.53E-07	0.00E+00	0.00E+00	3.53E-07
Total Curies/Year	**9.53E-05**	**8.62E-06**	**2.92E-06**	**6.82E-05**	**1.14E-03**	**1.21E-05**	**1.33E-03**

*Values are taken from *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2017* (FRNP 2018c).

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.

Table 4.2. Dose Calculations for Airborne Releases for CY 2017

Emission Sources	Dose to the Maximally Exposed Individual for the Plant (mrem)
Group D—C-709/C-710 Laboratory Hoods	3.2E-04
Group F—Seal Exhaust/Wet Air Group	5.3E-05
Northwest Plume Treatment System	6.5E-05
Northeast Plume Treatment Unit SP234	1.6E-06
Northeast Plume Treatment Unit SP235	5.0E-07
DUF_6 Conversion Facility	9.4E-07
Total from All Sources	**4.4E-04**

The hypothetical maximally exposed individual was calculated potentially to receive an effective dose equivalent of 0.00052 mrem, which is well below the NESHAP standard of 10 mrem. 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 2017

Effective Dose to Maximally Exposed Individual (mrem)	Percent of Standard (%)	Collective Effective Dose (person-rem)
4.4E-04	0.0044	3.8E-03

A complete summary of this emissions data can be found in the *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2017* (FRNP 2018c).

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 and the composite DOE-STD-1196-2011, Derived Concentration Technical Standard (DCS), for ingestion limits for all radionuclides (DOE 2011a).

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 an isotope is the concentration of the isotope 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 radioactive isotope 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 DCSs result in a dose that is higher than a person would actually receive. The DCS is different for each isotope 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 2017 (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) and a location near the nearest public water withdrawal location, Cairo, Illinois, (L306) were sampled. 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

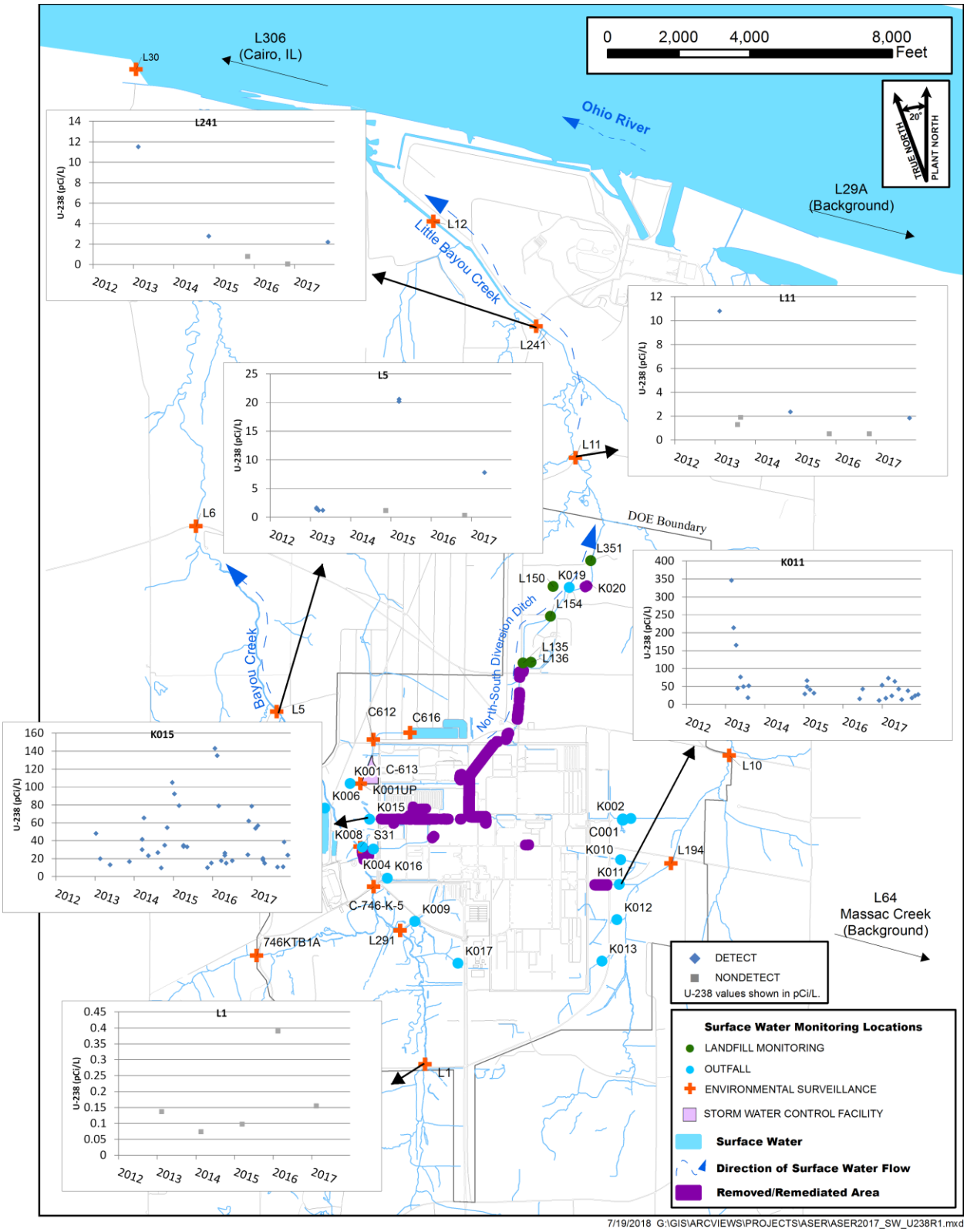

Figure 4.4. Surface Water Monitoring Locations with Uranium-238 Trends

part of a 2010 removal action for contaminated sediment associated with the Surface Water Operable Unit are denoted on the figure (DOE 2011b).

Isotopic analysis for multiple radionuclides is performed at each location unless the alpha and beta activity levels are below established threshold limits. The threshold limits were established by considering the isotopes that historically have been detected, identifying the two of those that have the lowest alpha and beta DCS values, respectively, and taking 10% of each of those values. The threshold limit established for alpha activity is 14 pCi/L (based on thorium-232 and plutonium-239) and the beta activity is 300 pCi/L (based on cesium-137). If, by the end of the CY, no threshold values have been exceeded at a location, then isotopic analysis for radionuclides is performed on the final sample to provide a data point for trending. Additional monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

In addition to the environmental surveillance surface water locations, samples were taken near the KPDES-permitted outfalls (001, 002, 004, 006, 008, 009, 010, 011, 012, 013, 015, 016, 017, 019, and 020) throughout the year. As with the environmental surveillance locations, isotopic analyses are not performed if the alpha and beta activity levels are below established threshold limits. If, by the end of the CY, no threshold values have been exceeded at a location, then isotopic analysis for radionuclides is performed on the final sample to provide a data point for trending.

Effluent sampling in surface water 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. Similarly, Northeast Plume effluent (C001) is monitored for technetium-99 according to the Operation and Maintenance Plan for the Northeast Plume Containment System Interim Remedial Action (DOE 2013).

Table 4.4 summarizes the isotopic detections of radionuclides at the surface water sampling locations and KPDES-permitted outfalls described. See Section 5.2 for discussion related to nonradiological surface water sampling.

Table 4.4. Ranges of Detected Radionuclides in 2017 Surface Water Samples

Isotope	Range
Technetium-99 (pCi/L)	2.68E+01–5.94E+01
Uranium-234 (pCi/L)	1.07E+00–2.04E+01
Uranium-235 (pCi/L)	1.02E+00–2.71E+00
Uranium-238 (pCi/L)	1.18E+00–7.84E+01

Detected technetium-99 results are from C001, including the maximum detected result. The results indicate a slight upward trend; however, all results are well below dose limits (see Section 4.1.6.3). 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 results is not unexpected. 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). 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 radionuclide isotopes were detected near the surface water collection inlet at Cairo during CY 2017. The maximum alpha and beta activities detected were 4.51 and 6.97 pCi/L, respectively. Maximum contaminant levels for alpha and beta activities are 15 pCi/L and 4 mrem/year, respectively.

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 radionuclide isotopes were detected, a default value of less than 0.09 mrem/year was used, as specified in the Environmental Monitoring Plan (FRNP 2018a).

In previous years, collective dose for annual ingestion of drinking water was estimating using the entire population within a 50-mile radius of the Paducah Site; however, most of these individuals within a 50-mile radius of the Paducah Site obtain their daily drinking water from sources other than those downgradient of the Paducah Site (see Sections 4.1.4 and 6.2). For 2017, 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 0.25 person-rem.

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.[7] 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 2017a). 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 0.11 mrem/year.

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.

4.1.6.4 Landfill leachate

Leachate from the C-746-U and C-746-S Landfills is sampled routinely and compared to DOE Order 458.1 limits. Summaries of detected radiological results are reported as surface water and included

[7] 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 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.

in Table 4.4. Additional monitoring results are available through the PEGASIS website at https://pegasis.pad.pppo.gov/.

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 replaced with public drinking water, resulting in the loss of groundwater as a drinking water source as an exposure route. A drinking water pathway for consumption of surface water at the nearest public drinking water source [Ohio River at Cairo, Illinois (L306)] is included in dose calculations for surface water. 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.

4.1.7.1 Sediment surveillance program

Sediment sampling at the Paducah Site in CY 2017 included radiological and nonradiological constituents (FRNP 2018a). This sampling occurred in June 2017. 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 2017 are similar in magnitude to those measured during previous years. Figure 4.5 shows the sampling locations. 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

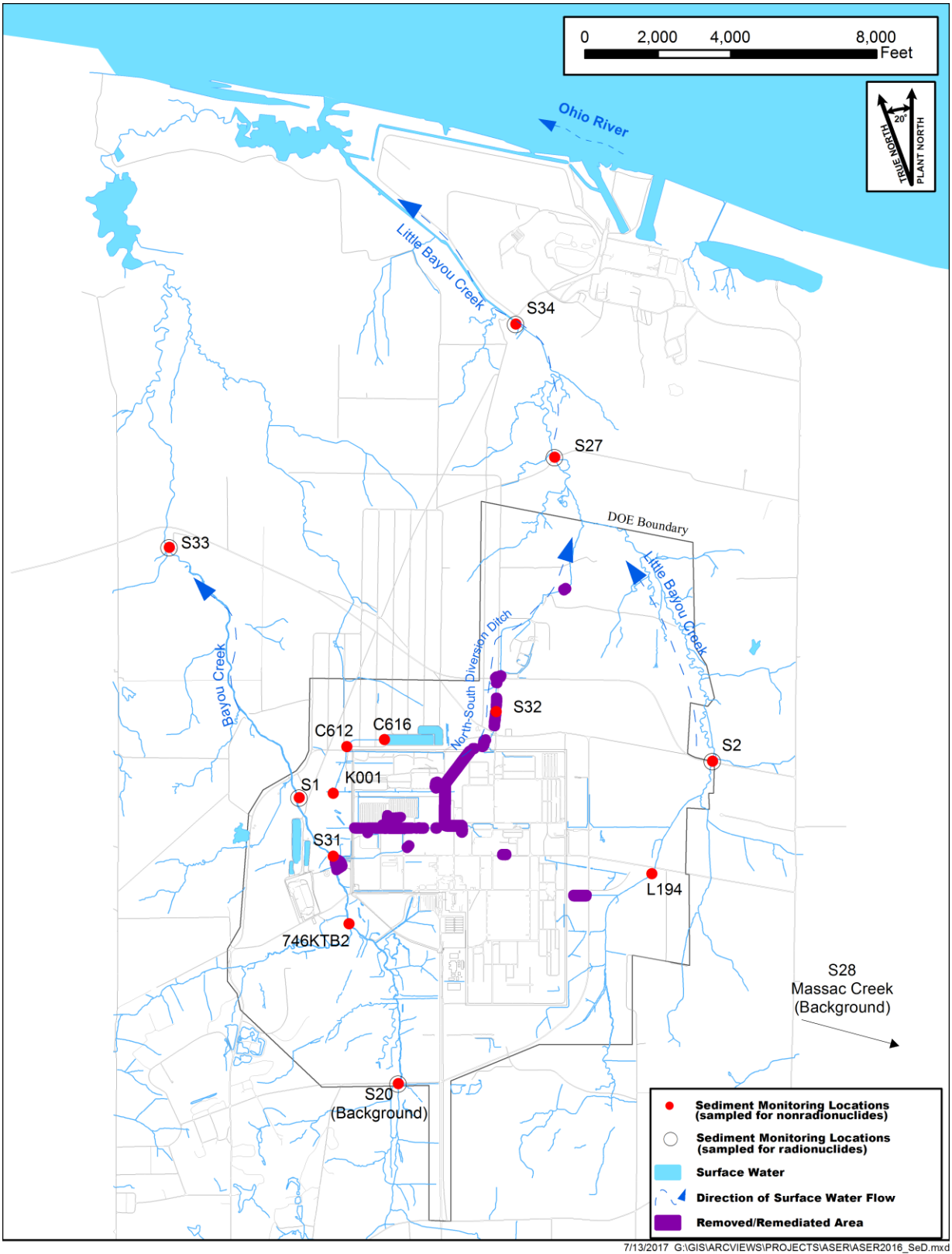

Figure 4.5. Sediment Monitoring Locations

Table 4.5. Radiological Activities for Sediment Sampling[a]

Parameter	S1	S2	S20 (background)	S27	S33	S33 (duplicate)	S34
Alpha activity	9.95E+00	6.52E+00	1.20E+01	1.75E+01	1.13E+01	9.21E+00	1.21E+01
Beta activity	1.82E+01	2.00E+01	1.27E+01	3.33E+01	1.09E+01	1.57E+01	1.49E+01
Americium-241	2.01E-02[b]	1.25E-01[b]	1.51E-01[b]	9.83E-02[b]	9.22E-02[b]	-1.03E-01[b]	-6.35E-02[b]
Cesium-137	6.76E-02	-1.24E-02[b]	-2.87E-03[b]	3.70E-03[b]	1.25E-02[b]	1.37E-02[b]	6.88E-03[b]
Neptunium-237	-5.56E-02[b]	-2.10E-01[b]	5.01E-02[b]	-6.80E-02[b]	8.98E-02[b]	-1.56E-01[b]	-4.13E-02[b]
Plutonium-238	-1.13E-01[b]	9.87E-02[b]	6.28E-02[b]	-1.35E-02[b]	8.15E-02[b]	-7.56E-02[b]	5.56E-02[b]
Plutonium-239/240	-1.56E-02[b]	8.31E-02[b]	-1.10E-01[b]	-7.84E-02[b]	1.03E-01[b]	5.46E-02[b]	5.56E-02[b]
Technetium-99	7.56E+00	8.97E-01[b]	8.42E-01[b]	3.90E+01	9.42E-01[b]	1.33E+00[b]	3.39E-01[b]
Thorium-230	7.92E-01	7.49E-01	6.46E-01[b]	1.81E+00	6.68E-01	9.11E-01	1.74E+00
Total Uranium	6.54E+00	3.39E+00	1.95E+00	6.31E+00	1.31E+00	2.22E+00	2.17E+00
Uranium-234	2.79E+00	7.98E-01	9.54E-01	1.86E+00	5.00E-01	1.05E+00	1.33E+00
Uranium-235	2.73E-01	9.37E-02[b]	3.06E-01[b]	5.18E-02[b]	2.72E-01[b]	2.31E-01[b]	1.89E-01[b]
Uranium-238	3.48E+00	2.50E+00	6.89E-01	4.40E+00	5.42E-01	9.36E-01	6.43E-01

[a] Units are in pCi/g for all.
[b] Result reported at concentrations less than the laboratory's reporting limit.

downstream of the plant site. Other radionuclides present above background values presented in *Methods for Conducting Risk Assessments and Risk Evaluations* (DOE 2017a) are technetium-99 at locations S1 and S27 and thorium-230 at locations S27 and S34.

4.1.7.2 Sediment dose

For the purpose of calculating dose to the hypothetical maximally exposed individual, it is postulated 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 2017a), 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 location S20 are assumed to be background and 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 2017. The highest annual dose was calculated to be at location S27 (0.05 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., S27). 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 2017 Incidental Ingestion of Sediment

	Committed Effective Dose Equivalent (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]	1.57E-03	0.00E+00	3.27E-03	7.09E-04	0.00E+00	2.65E-05	6.69E-03	2.01E-03	1.32E-02	6.32E-03	3.38E-02
S1[b]	0.00E+00	1.36E-02	0.00E+00	0.00E+00	0.00E+00	2.12E-04	1.51E-03	3.88E-03	0.00E+00	2.56E-02	4.48E-02
S2[b]	0.00E+00	0.00E+00	0.00E+00	4.01E-04	1.02E-03	1.70E-06	1.06E-03	0.00E+00	0.00E+00	1.66E-02	1.91E-02
S27[b]	0.00E+00	7.44E-04	0.00E+00	0.00E+00	0.00E+00	1.20E-03	1.20E-02	1.91E-03	0.00E+00	3.41E-02	***5.00E-02***
S33[b]	0.00E+00	2.64E-03	0.00E+00	0.00E+00	9.68E-04	9.30E-06	1.49E-03	0.00E+00	0.00E+00	4.60E-04	5.57E-03
S34[b]	0.00E+00	1.38E-03	0.00E+00	0.00E+00	6.83E-04	0.00E+00	1.13E-02	8.00E-04	0.00E+00	0.00E+00	1.42E-02
Net Exposure from Paducah Site to the Maximally Exposed Individual[a,b,c,d] (Downstream Little Bayou) =											**5.0E-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 2017a), 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, and taken up by food crops. 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

Deer monitoring has been eliminated from the Paducah Site monitoring program. During FY 2011, DOE performed an extensive review of data sets from 20 years of deer harvesting events. As a result of this review, DOE eliminated the deer monitoring 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 the Paducah Site security fence.

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 2017, 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 15 of 51 locations were consistently above background levels, as reported in the *Annual Report on External Radiation Monitoring for Calendar Year 2017, Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (FRNP 2018d). These locations were adjacent to or in close proximity to the Paducah Site security fence in the vicinity of UF_6 cylinder storage yards. Because security protocols prohibited the public from gaining prolonged access to the PGDP boundary fence in CY 2017, the potential radiation doses calculated at or in close proximity to the fence are not realistic.

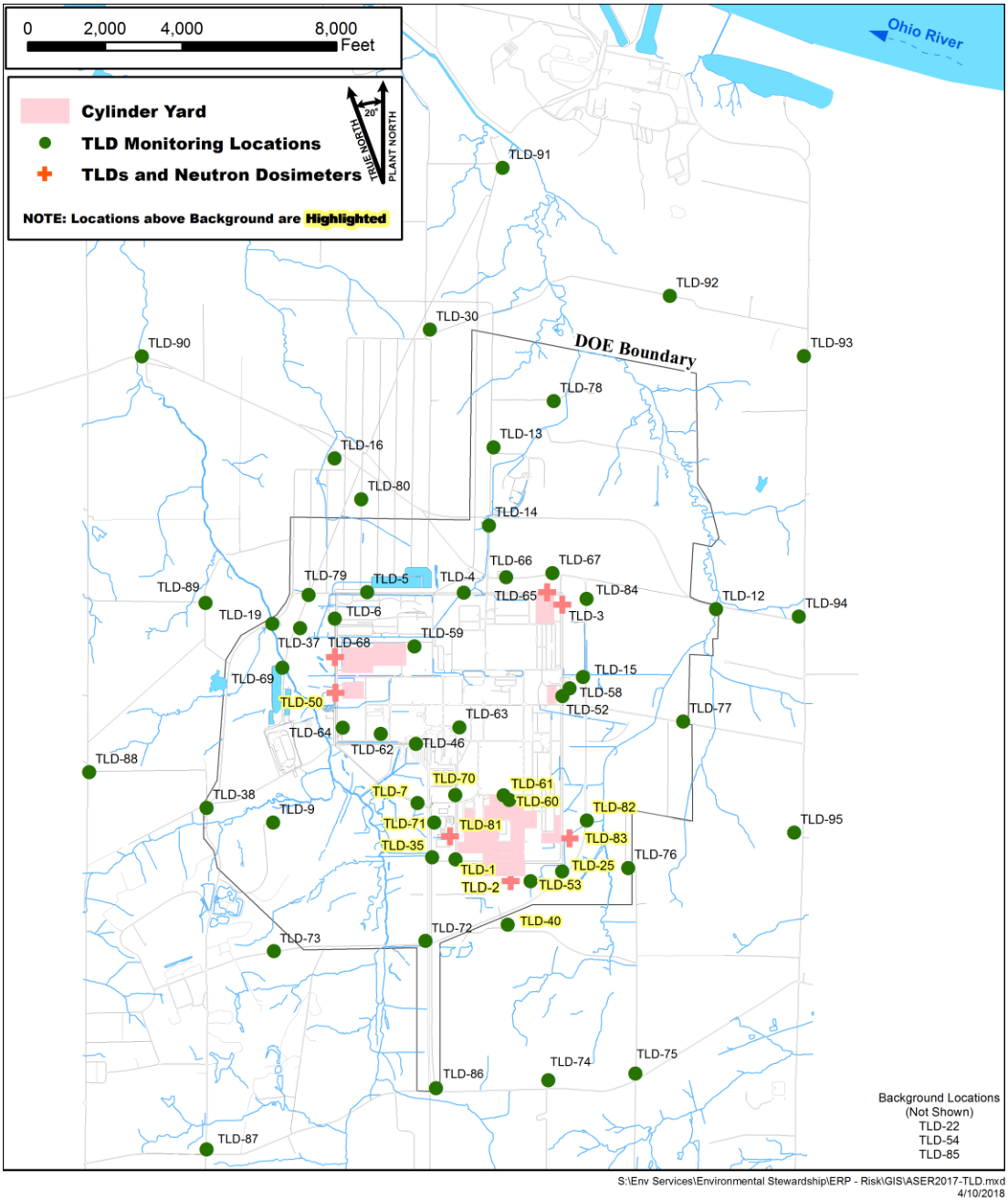

Figure 4.6. Dosimeter Locations in the Vicinity of the Paducah Site

4.1.10.2 Direct radiation dose

Due to Paducah Site security protocols in CY 2017, no members of the public routinely were allowed near the security fence. 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 3.76 mrem/year in a scenario where areas of highest exposure are visited 80 hours/year. In 2017, 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 2017, 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 was calculated to be at background levels.

For 2017, 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 0.56 person-rem (DOE 2017a).

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 2017 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, 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 4.1 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.

Table 4.7. Summary of Potential Radiological Dose to the Maximally Exposed Individual from the Paducah Site for CY 2017[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]	4.4E-04	0.00044%	3.8E-03	~534,116
Water[d]				
Ingestion of drinking water[e]	9.0E-02	0.09%	2.5E-01[f]	2,830
Incidental ingestion of surface water	1.1E-01	0.11%	[g]	[g]
Sediments (incidental ingestion)	5.0E-02	0.050%	[g]	[g]
Direct radiation	3.8E+00	3.8%	5.6E-01[h]	150
All Relevant Pathways[a]	**4.1E+00**[b]	**4.1%**	**8.1E-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 Containment System Alternate Treatment Unit, DUF_6 conversion activities, and C-709 and C-710 Seal Exhaust/Wet Air Group.
[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 and sediment 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 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 2017a).

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 0.81 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 2017 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 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 biota concentration guide 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 biota concentration guides 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 2017 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	2.01E-02[c]	6.80E+05	2.95E-08	No	2.95E-08
Cs-137	-4.53E-01[c]	1.05E+03	-4.32E-04	No	6.76E-02	4.93E+04	1.37E-06	No	-4.31E-04
K-40	3.03E+00[c]	2.90E+03	1.05E-03	No	N/A	5.79E+04	N/A	No	1.05E-03
Np-237	-5.29E-02[c]	6.85E+01	-7.72E-04	Yes	-5.56E-02[c]	7.86E+04	-7.08E-07	No	-7.73E-04
Pu-238	-2.53E-01[c]	1.76E+02	-1.44E-03	Yes	-1.13E-01[c]	3.95E+06	-2.86E-08	No	-1.44E-03
Pu-239[d]	-3.51E-02[c]	1.87E+02	-1.88E-04	Yes	-1.56E-02[c]	7.05E+06	-2.21E-09	No	-1.88E-04
Tc-99	-8.32E+00[c]	2.47E+06	-3.37E-06	No	7.56E+00	4.59E+05	1.65E-05	No	1.31E-05
Th-230	N/A	2.57E+03	N/A	Yes	7.92E-01	2.74E+06	2.89E-07	No	2.89E-07
Th-234	1.07E+02[c]	2.66E+05	4.02E-04	Yes	N/A	4.32E+04	N/A	No	4.02E-04
U-234	5.04E+00	2.02E+02	2.50E-02	Yes	2.79E+00	3.03E+06	9.21E-07	No	2.50E-02
U-235	1.84E+00	2.18E+02	8.45E-03	Yes	2.73E-01	1.10E+05	2.49E-06	No	8.45E-03
U-238	7.80E+00	2.24E+02	3.49E-02	Yes	3.48E+00	4.29E+04	8.11E-05	No	3.50E-02
Summed	-	-	6.69E-02	-	-	-	1.02E-04	-	6.70E-02

Table 4.8. Bayou Creek 2017 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

	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	2.01E-02[c]	5.15E+03	3.91E-06	Yes	3.91E-06
Cs-137	-4.53E-01[c]	4.27E+01	-1.06E-02	Yes	6.76E-02	3.13E+03	2.16E-05	Yes	-1.06E-02
K-40	3.03E+00[c]	2.49E+02	1.22E-02	Yes	N/A	4.42E+03	N/A	Yes	1.22E-02
Np-237	-5.29E-02[c]	1.16E+04	-4.57E-06	No	-5.56E-02[c]	7.63E+03	-7.29E-06	Yes	-1.19E-05
Pu-238	-2.53E-01[c]	5.51E+02	-4.60E-04	No	-1.13E-01[c]	5.73E+03	-1.97E-05	Yes	-4.79E-04
Pu-239[d]	-3.51E-02[c]	6.22E+02	-5.64E-05	No	-1.56E-02[c]	5.87E+03	-2.66E-06	Yes	-5.91E-05
Tc-99	-8.32E+00[c]	6.67E+05	-1.25E-05	Yes	7.56E+00	4.14E+04	1.83E-04	Yes	1.70E-04
Th-230	N/A	1.39E+04	N/A	No	7.92E-01	1.04E+04	7.60E-05	Yes	7.60E-05
Th-234	1.07E+02[c]	3.80E+06	2.82E-05	No	N/A	4.32E+03	N/A	Yes	2.82E-05
U-234	5.04E+00	6.84E+02	7.37E-03	No	2.79E+00	5.27E+03	5.29E-04	Yes	7.90E-03
U-235	1.84E+00	7.37E+02	2.50E-03	No	2.73E-01	3.79E+03	7.21E-05	Yes	2.57E-03
U-238	7.80E+00	7.57E+02	1.03E-02	No	3.48E+00	2.49E+03	1.40E-03	Yes	1.17E-02
Summed	-	-	2.12E-02	-	-	-	2.25E-03	-	2.35E-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	2.01E-02[c]	3.65E+25	5.51E-28	No	5.51E-28
Cs-137	-4.53E-01[c]	5.99E+05	-7.56E-07	No	6.76E-02	3.65E+25	1.85E-27	No	-7.56E-07
K-40	3.03E+00[c]	1.93E+06	1.57E-06	No	N/A	3.65E+25	N/A	No	1.57E-06
Np-237	-5.29E-02[c]	6.49E+06	-8.15E-09	No	-5.56E-02[c]	3.65E+25	-1.52E-27	No	-8.15E-09
Pu-238	-2.53E-01[c]	1.89E+05	-1.34E-06	No	-1.13E-01[c]	3.65E+25	-3.10E-27	No	-1.34E-06
Pu-239[d]	-3.51E-02[c]	2.01E+05	-1.75E-07	No	-1.56E-02[c]	3.65E+25	-4.27E-28	No	-1.75E-07
Tc-99	-8.32E+00[c]	1.54E+07	-5.41E-07	No	7.56E+00	3.65E+25	2.07E-25	No	-5.41E-07
Th-230	N/A	4.52E+05	N/A	No	7.92E-01	3.65E+25	2.17E-26	No	2.17E-26
Th-234	1.07E+02[c]	4.31E+06	2.48E-05	No	N/A	3.65E+25	N/A	No	2.48E-05
U-234	5.04E+00	4.05E+05	1.24E-05	No	2.79E+00	3.65E+25	7.64E-26	No	1.24E-05
U-235	1.84E+00	4.20E+05	4.38E-06	No	2.73E-01	3.65E+25	7.48E-27	No	4.38E-06
U-238	7.80E+00	4.06E+05	1.92E-05	No	3.48E+00	3.65E+25	9.53E-26	No	1.92E-05
Summed	-	-	5.96E-05	-	-	-	4.05E-25	-	5.96E-05
	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	2.01E-02[c]	3.65E+26	5.51E-29	No	5.51E-29
Cs-137	-4.53E-01[c]	4.93E+07	-9.18E-09	No	6.76E-02	3.65E+26	1.85E-28	No	-9.18E-09
K-40	3.03E+00[c]	5.79E+07	5.23E-08	No	N/A	3.65E+26	N/A	No	5.23E-08
Np-237	-5.29E-02[c]	7.86E+07	-6.73E-10	No	-5.56E-02[c]	3.65E+26	-1.52E-28	No	-6.73E-10
Pu-238	-2.53E-01[c]	3.95E+09	-6.41E-11	No	-1.13E-01[c]	3.65E+26	-3.10E-28	No	-6.41E-11
Pu-239[d]	-3.51E-02[c]	7.05E+09	-4.98E-12	No	-1.56E-02[c]	3.65E+26	-4.27E-29	No	-4.98E-12
Tc-99	-8.32E+00[c]	4.59E+08	-1.81E-08	No	7.56E+00	3.65E+26	2.07E-26	No	-1.81E-08
Th-230	N/A	2.74E+09	N/A	No	7.92E-01	3.65E+26	2.17E-27	No	2.17E-27
Th-234	1.07E+02[c]	4.32E+07	2.48E-06	No	N/A	3.65E+26	N/A	No	2.48E-06
U-234	5.04E+00	3.03E+09	1.66E-09	No	2.79E+00	3.65E+26	7.64E-27	No	1.66E-09
U-235	1.84E+00	1.10E+08	1.68E-08	No	2.73E-01	3.65E+26	7.48E-28	No	1.68E-08
U-238	7.80E+00	4.29E+07	1.82E-07	No	3.48E+00	3.65E+26	9.53E-27	No	1.82E-07
Summed	-	-	2.70E-06	-	-	-	4.05E-26	-	2.70E-06

Summed total ratio for limiting organism: 8.31E-02.
Summed water ratio for limiting organism: 8.09E-02.
Summed sediment ratio for limiting organism: 2.28E-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 2017 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 2017 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	9.83E-02[c]	6.80E+05	1.44E-07	No	1.44E-07
Cs-137	N/A	1.05E+03	N/A	No	3.70E-03[c]	4.93E+04	7.50E-08	No	7.50E-08
Np-237	N/A	6.85E+01	N/A	Yes	-6.80E-02[c]	7.86E+04	-8.65E-07	No	-8.65E-07
Pu-238	N/A	1.76E+02	N/A	Yes	-1.35E-02[c]	3.95E+06	-3.42E-09	No	-3.42E-09
Pu-239[d]	N/A	1.87E+02	N/A	Yes	-7.84E-02[c]	7.05E+06	-1.11E-08	No	-1.11E-08
Tc-99	-1.26E+02[c]	2.47E+06	-5.11E-05	No	3.90E+01	4.59E+05	8.50E-05	No	3.39E-05
Th-230	5.48E-02[c]	2.57E+03	2.13E-05	Yes	1.81E+00	2.74E+06	6.60E-07	No	2.20E-05
U-234	1.07E+00	2.02E+02	5.30E-03	Yes	1.86E+00	3.03E+06	6.14E-07	No	5.30E-03
U-235	-4.87E-02[c]	2.18E+02	-2.24E-04	Yes	5.18E-02[c]	1.10E+05	4.73E-07	No	-2.23E-04
U-238	1.84E+00	2.24E+02	8.23E-03	Yes	4.40E+00	4.29E+04	1.03E-04	No	8.33E-03
Summed	-	-	1.33E-02	-	-	-	1.89E-04	-	1.35E-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	9.83E-02[c]	5.15E+03	1.91E-05	Yes	1.91E-05
Cs-137	N/A	4.27E+01	N/A	Yes	3.70E-03[c]	3.13E+03	1.18E-06	Yes	1.18E-06
Np-237	N/A	1.16E+04	N/A	No	-6.80E-02[c]	7.63E+03	-8.91E-06	Yes	-8.91E-06
Pu-238	N/A	5.51E+02	N/A	No	-1.35E-02[c]	5.73E+03	-2.36E-06	Yes	-2.36E-06
Pu-239[d]	N/A	6.22E+02	N/A	No	-7.84E-02[c]	5.87E+03	-1.34E-05	Yes	-1.34E-05
Tc-99	-1.26E+02[c]	6.67E+05	-1.89E-04	Yes	3.90E+01	4.14E+04	9.42E-04	Yes	7.53E-04
Th-230	5.48E-02[c]	1.39E+04	3.95E-06	No	1.81E+00	1.04E+04	1.74E-04	Yes	1.78E-04
U-234	1.07E+00	6.84E+02	1.57E-03	No	1.86E+00	5.27E+03	3.53E-04	Yes	1.92E-03
U-235	-4.87E-02[c]	7.37E+02	-6.61E-05	No	5.18E-02[c]	3.79E+03	1.37E-05	Yes	-5.24E-05
U-238	1.84E+00	7.57E+02	2.43E-03	No	4.40E+00	2.49E+03	1.77E-03	Yes	4.20E-03
Summed	-	-	3.75E-03	-	-	-	3.24E-03	-	6.99E-03
	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	9.83E-02[c]	3.65E+25	2.69E-27	No	2.69E-27
Cs-137	N/A	5.99E+05	N/A	No	3.70E-03[c]	3.65E+25	1.01E-28	No	1.01E-28
Np-237	N/A	6.49E+06	N/A	No	-6.80E-02[c]	3.65E+25	-1.86E-27	No	-1.86E-27
Pu-238	N/A	1.89E+05	N/A	No	-1.35E-02[c]	3.65E+25	-3.70E-28	No	-3.70E-28
Pu-239[d]	N/A	2.01E+05	N/A	No	-7.84E-02[c]	3.65E+25	-2.15E-27	No	-2.15E-27
Tc-99	-1.26E+02[c]	1.54E+07	-8.19E-06	No	3.90E+01	3.65E+25	1.07E-24	No	-8.19E-06
Th-230	5.48E-02[c]	4.52E+05	1.21E-07	No	1.81E+00	3.65E+25	4.96E-26	No	1.21E-07
U-234	1.07E+00	4.05E+05	2.64E-06	No	1.86E+00	3.65E+25	5.10E-26	No	2.64E-06
U-235	-4.87E-02[c]	4.20E+05	-1.16E-07	No	5.18E-02[c]	3.65E+25	1.42E-27	No	-1.16E-07
U-238	1.84E+00	4.06E+05	4.53E-06	No	4.40E+00	3.65E+25	1.21E-25	No	4.53E-06
Summed	-	-	-1.01E-06	-	-	-	1.29E-24	-	-1.01E-06

Table 4.9. Little Bayou Creek 2017 Evaluation of Dose to Aquatic and Terrestrial Biota[a] (Continued)

	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	9.83E-02[c]	3.65E+26	2.69E-28	No	2.69E-28
Cs-137	N/A	4.93E+07	N/A	No	3.70E-03[c]	3.65E+26	1.01E-29	No	1.01E-29
Np-237	N/A	7.86E+07	N/A	No	-6.80E-02[c]	3.65E+26	-1.86E-28	No	-1.86E-28
Pu-238	N/A	3.95E+09	N/A	No	-1.35E-02[c]	3.65E+26	-3.70E-29	No	-3.70E-29
Pu-239[d]	N/A	7.05E+09	N/A	No	-7.84E-02[c]	3.65E+26	-2.15E-28	No	-2.15E-28
Tc-99	-1.26E+02[c]	4.59E+08	-2.75E-07	No	3.90E+01	3.65E+26	1.07E-25	No	-2.75E-07
Th-230	5.48E-02[c]	2.74E+09	2.00E-11	No	1.81E+00	3.65E+26	4.96E-27	No	2.00E-11
U-234	1.07E+00	3.03E+09	3.53E-10	No	1.86E+00	3.65E+26	5.10E-27	No	3.53E-10
U-235	-4.87E-02[c]	1.10E+08	-4.44E-10	No	5.18E-02[c]	3.65E+26	1.42E-28	No	-4.44E-10
U-238	1.84E+00	4.29E+07	4.29E-08	No	4.40E+00	3.65E+26	1.21E-26	No	4.29E-08
Summed	-	-	-2.32E-07	-	-	-	1.29E-25	-	-2.32E-07

Summed total ratio for limiting organism: 1.68E-02.
Summed water ratio for limiting organism: 1.36E-02.
Summed sediment ratio for limiting organism: 3.27E-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 2017 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 surficial contamination, while specific Authorized Limits have been derived to control whether items with potential volumetric contamination are released. In those cases where volumetric Authorized Limits have not been established, release is determined based on a comparison to established background radionuclide concentrations. These background radionuclide concentrations are documented in the *Methods for Conducting Risk Assessments and Risk Evaluations* (DOE 2017a), where appropriate.

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 2017, FFS/FRNP authorized, with concurrence from DOE, 537 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. Items with the potential for volumetric contamination were assessed to determine if sampling was necessary to support the release.

The results of volumetric samples were used to verify that no radioactive materials had been added or that results were below the appropriate release limit.

In 2017, SST authorized, with concurrence from DOE, 331 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 2017, 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 2017, 1.013 million 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.

DOE placed 640 tons of 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 2017 include building demolition debris. Table 4.10 provides a summary of Authorized Limit disposal at the C-746-U Landfill during CY 2017 and the cumulative totals since Authorized Limit disposal began in May 2003.

Table 4.10. C-746-U Landfill Authorized Limit Disposal

Cumulative Activity from 2017 Disposal			Total Activity from Disposal 5/21/03 to 12/31/17		
Isotope	**Activity (Curies)**		**Activity (Curies)**	**Source Term Limit (Curies)**	**Percent Utilized***
Americium-241	3.6E-04		7.3E-03	79	0.01%
Cesium-137	1.9E-04		1.1E-02	43	0.03%
Neptunium-237	3.6E-04		1.2E-02	12	0.10%
Plutonium-238	6.0E-05		1.9E-03	88	0.00%
Plutonium-239/240	8.2E-04		1.7E-02	162	0.01%
Technetium-99	3.4E-02		1.1E+00	117	0.95%
Thorium-228	4.2E-04		7.1E-02	9	0.79%
Thorium-230	6.3E-03		2.2E-01	230	0.10%
Thorium-232	4.2E-04		7.1E-02	9	0.79%
Uranium-234	2.1E-02		3.4E-01	360	0.09%
Uranium-235	1.2E-03		1.6E-02	15	0.11%
Uranium-238	4.0E-02		3.7E-01	360	0.10%
				Total % 3.09%	

Waste streams added (2017)	2	Waste streams disposed of (2003–2017)	293
Mass disposed of (2017)	640 tons	Mass disposed of (2003–2017)	125,057 tons
		Volume of current cells	386,169 yd^3
		Remaining cell volume	49,990 yd^3

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

4.3 UNPLANNED RADIOLOGICAL RELEASES

There were no unplanned radiological releases in 2017.

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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,[8] 019, and 020. The permit combined outfalls that formerly were covered under both this permit and KPDES Permit KY0102083. 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.

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, with hyperlinks to the reports, if available. 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 2017 ranging from 1.79 µg/kg to 148 µg/kg, within the acceptable risk range. According to *Methods for Conducting Risk Assessments and Risk Evaluations*, the no action level[9] for Total PCBs is 179 µg/kg, and the action level[10] is 17,900 µg/kg for the recreational user (DOE 2017a). The recreational user is used for comparison because it is the most reasonably anticipated scenario. Additional monitoring results are available through the PEGASIS website athttps://pegasis.pad.pppo.gov/.

[8] Permit Number KY0004049 also includes MCS as a permittee for Outfall 017.
[9] 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.
[10] 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.

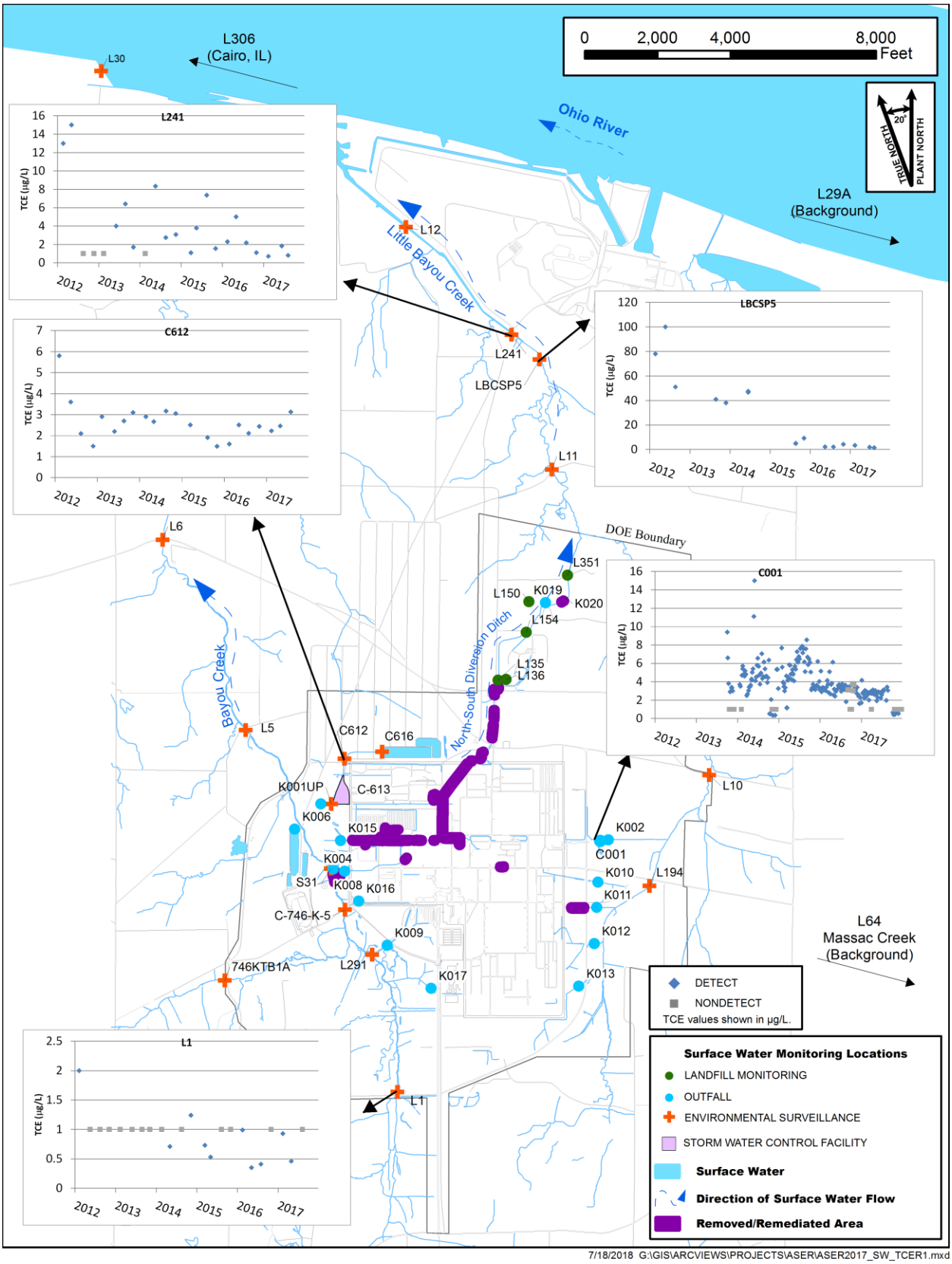

Figure 5.1. Surface Water and Seep Monitoring Locations with TCE Trends

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 2017 (January–March) Second Quarter 2017 (April–June) Third Quarter 2017 (July–September) Fourth Quarter 2017 (October–December)	L135, L136, L154*
C-746-U Landfill Surface Water *Quarterly Compliance Monitoring Reports*: First Quarter 2017 (January–March) Second Quarter 2017 (April–June) Third Quarter 2017 (July–September) Fourth Quarter 2017 (October–December)	L150, L154*, L351
KPDES** Monthly 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, K001UP, L1, L10, L11, L12, L194, L241, L291, L29A, L30, L306, L5, L6, L64, S31
Seep	LBCSP5
Northeast Plume Effluent *Semiannual FFA Progress Reports:* Second Half of FY 2017 (Data reported January–June 2017) First Half of FY 2018 (Data reported July–December 2017)	C001

*Location is listed for both C-746-S and C-746-T and for C-746-U.
**During 2017, sampling was performed as part of a Toxicity Reduction Evaluation (TRE) under the KPDES permit. Data from the TRE are included in this section.

Table 5.2. Ranges of Detected Analytes in 2017 Surface Water Samples

Analyte	Range
Anions	
Chloride (µg/L)	219–363,000
Fluoride (µg/L)	437–532
Nitrate as Nitrogen (µg/L)	205–2,630
Nitrite (µg/L)	45.2–45.2
Orthophosphate (µg/L)	69.6–80.9
Sulfate (µg/L)	1,750–187,000
Wet Chemistry Parameters	
Ammonia (µg/L)	0.176–57.6
Ammonia as Nitrogen (µg/L)	21.1–47,100
Bicarbonate (µg/L)	505,000–575,000
Biochemical Oxygen Demand (µg/L)	4,110–11,300
Carbonaceous Biochemical Oxygen Demand (µg/L)	1,120–198,000
Chemical Oxygen Demand (µg/L)	19,900–108,000
Dissolved Solids (µg/L)	57,100–867,000
Fecal Coliform (col/100 mL)	1.00–57.0
Hardness—Total as $CaCO_3$ (µg/L)	21,200–482,000
Suspended Solids (µg/L)	600–780,000

Table 5.2. Ranges of Detected Analytes in 2017 Surface Water Samples (Continued)

Analyte	Range
Total Organic Carbon (µg/L)	2,780–26,800
Total Solids (µg/L)	60,000–420,000
Volatile Organic Compounds	
1,1,1-Trichloroethane (µg/L)	0.57-0.57
Acetone (µg/L)	1.95–4.98
Bromodichloromethane (µg/L)	0.340–3.13
Chloroform (µg/L)	0.530–6.19
cis-1,2-Dichloroethene (µg/L)	0.340–4.83
Dibromochloromethane (µg/L)	0.340–1.30
Toluene (µg/L)	5.50–5.70
Trichloroethene (µg/L)	0.340–5.82
Herbicides/Pesticides/PCBs	
2,4-D (µg/L)	0.0847–14.1
4,4'-DDD (µg/L)	0.00582–0.00582
4,4'-DDE (µg/L)	0.00235–0.00235
alpha-BHC (µg/L)	0.00549–0.00549
gamma-Chlordane (µg/L)	0.00192–0.00192
Dieldrin (µg/L)	0.00368–0.00368
Endosulfan I (µg/L)	0.00620–0.00620
Endosulfan sulfate (µg/L)	0.00289–0.00289
Endrin (µg/L)	0.00294–0.0034
Endrin aldehyde (µg/L)	0.00335–0.0770
Heptachlor (µg/L)	0.0378–0.0378
Methoxychlor (µg/L)	0.0112–0.0112
PCB-1242 (µg/L)	0.0399-0.0506
PCB-1248 (µg/L)	0.0425–0.0513
PCB-1254 (µg/L)	0.0475–0.0475
PCB-1260 (µg/L)	0.0369–0.171
Total PCBs (µg/L)	0.0369–0.171
Other Organics	
Oil and Grease (µg/L)	1,130–4,370
Metals	
Aluminum (µg/L)	34.1–447
Aluminum, Dissolved (µg/L)	29.3–30.6
Antimony (µg/L)	1.04–1.04
Arsenic (µg/L)	2.00–5.00
Arsenic, Dissolved (µg/L)	2.01–2.82
Barium (µg/L)	10.5–127
Barium, Dissolved (µg/L)	13.5–204
Boron (µg/L)	7.52–252
Boron, Dissolved (µg/L)	8.50–45.2
Calcium (µg/L)	9,760–152,000
Calcium, Dissolved (µg/L)	10,100–53,400
Chromium (µg/L)	3.19–3.19
Chromium, hexavalent (µg/L)	5.01–14.7
Cobalt (µg/L)	0.302–1.05
Copper (µg/L)	0.360–7.10
Copper, Dissolved (µg/L)	0.617–5.59
Iron (µg/L)	81.4–2,460
Iron, Dissolved (µg/L)	35.2–231
Lead (µg/L)	0.500–1.05

Table 5.2. Ranges of Detected Analytes in 2017 Surface Water Samples (Continued)

Analyte	Range
Lithium (µg/L)	3.15–6.23
Lithium, Dissolved (µg/L)	3.07–3.26
Magnesium (µg/L)	1,630–41,400
Magnesium, Dissolved (µg/L)	1,690–12,600
Manganese (µg/L)	13.2–209
Manganese, Dissolved (µg/L)	1.24–119
Mercury (µg/L)	0.0690–0.110
Mercury, Dissolved (µg/L)	0.108–2.71
Molybdenum (µg/L)	0.218–41.4
Molybdenum, Dissolved (µg/L)	0.547–40.0
Nickel (µg/L)	0.569–66.3
Nickel, Dissolved (µg/L)	0.614–2.28
Phosphorous (µg/L)	23.2–4,160
Phosphorous, Dissolved (µg/L)	20.2–236
Potassium (µg/L)	703–5,650
Potassium, Dissolved (µg/L)	711–2,960
Selenium (µg/L)	2.07–5.00
Selenium, Dissolved (µg/L)	2.04–2.99
Silver (µg/L)	0.317–0.397
Sodium (µg/L)	624–65,200
Sodium, Dissolved (µg/L)	5,840–43,000
Strontium (µg/L)	69.5–2,290
Strontium, Dissolved (µg/L)	73.7–2,290
Thallium (µg/L)	0.944–1.04
Thorium (µg/L)	0.889–0.94
Thorium, Dissolved (µg/L)	1.15–1.15
Tin (µg/L)	1.40–1.40
Tin, Dissolved (µg/L)	2.88–2.88
Titanium (µg/L)	2.00–7.56
Uranium (µg/L)	0.075–393
Uranium, Dissolved (µg/L)	0.0850–53.8
Vanadium (µg/L)	3.46–4.27
Vanadium, Dissolved (µg/L)	3.55–3.66
Zinc (µg/L)	3.38–115
Zinc, Dissolved (µg/L)	4.45–49.1

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.

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 (Figure 5.2). 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.

Figure 5.2. PGDP Fire Services

DOE's Deactivation and Remediation Contractor, FFS/FRNP, is responsible for wildland fire management for areas of the site outside WKWMA. WKWMA is within the West McCracken Fire Department's district.

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. The expansion took effect January 1, 2012, after a new five-year license agreement was signed between the Kentucky Department of Fish and Wildlife Resources and DOE. The license agreement was renewed in August 2016 with updates, including the acceptance of mountain biking; use of starting pistols; additional areas for shotgun slug use; and clarification that if a recreational user needs to enter an area not designated for public use, the WKWMA representative will contact the Plant Shift Superintendent and

PGDP Protective Force. 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 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. This 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 2017 and shows the 2016 TCE plume associated with the Paducah Site (FPDP 2017b). 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.

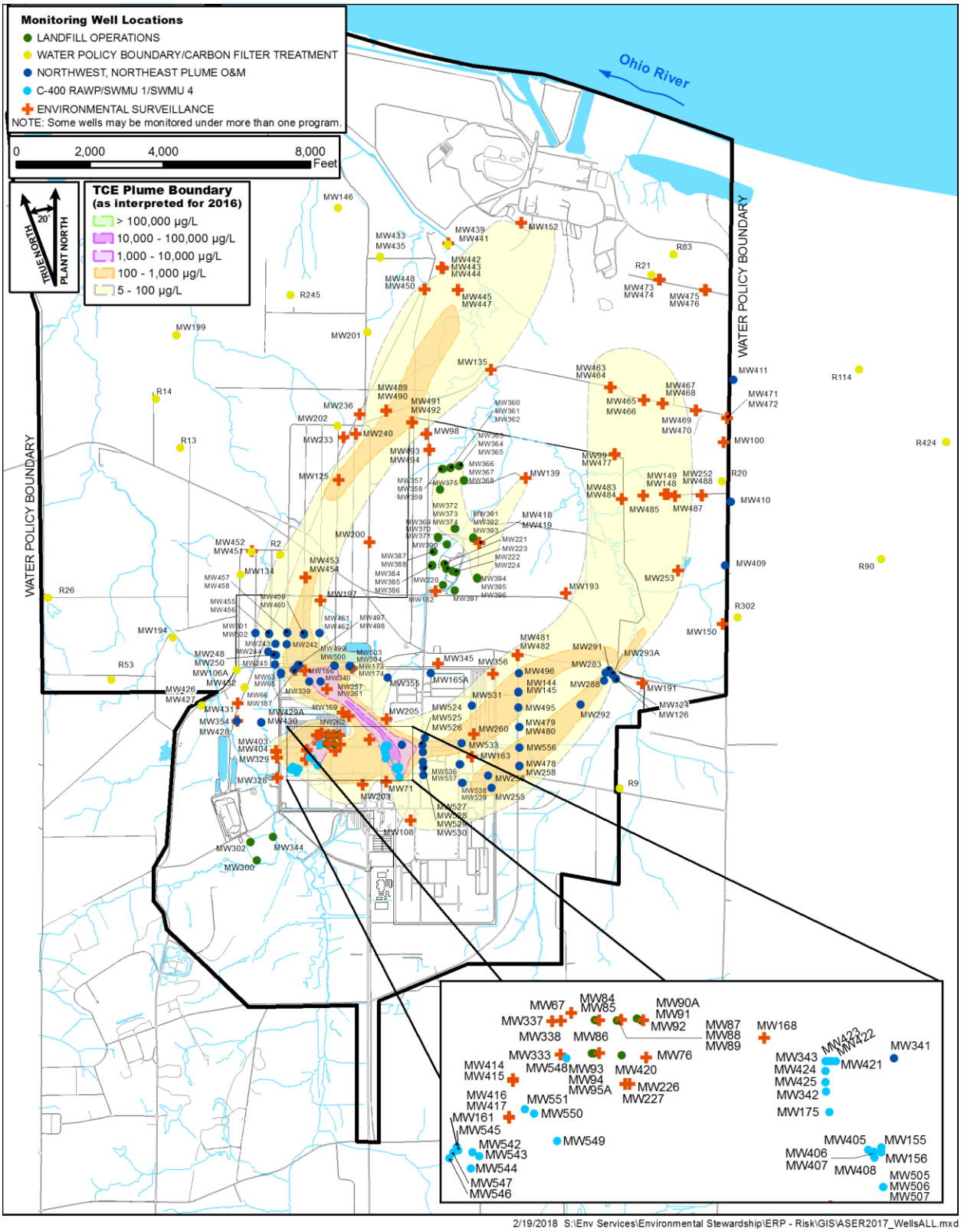


Figure 6.1. Monitoring Wells Sampled in CY 2017

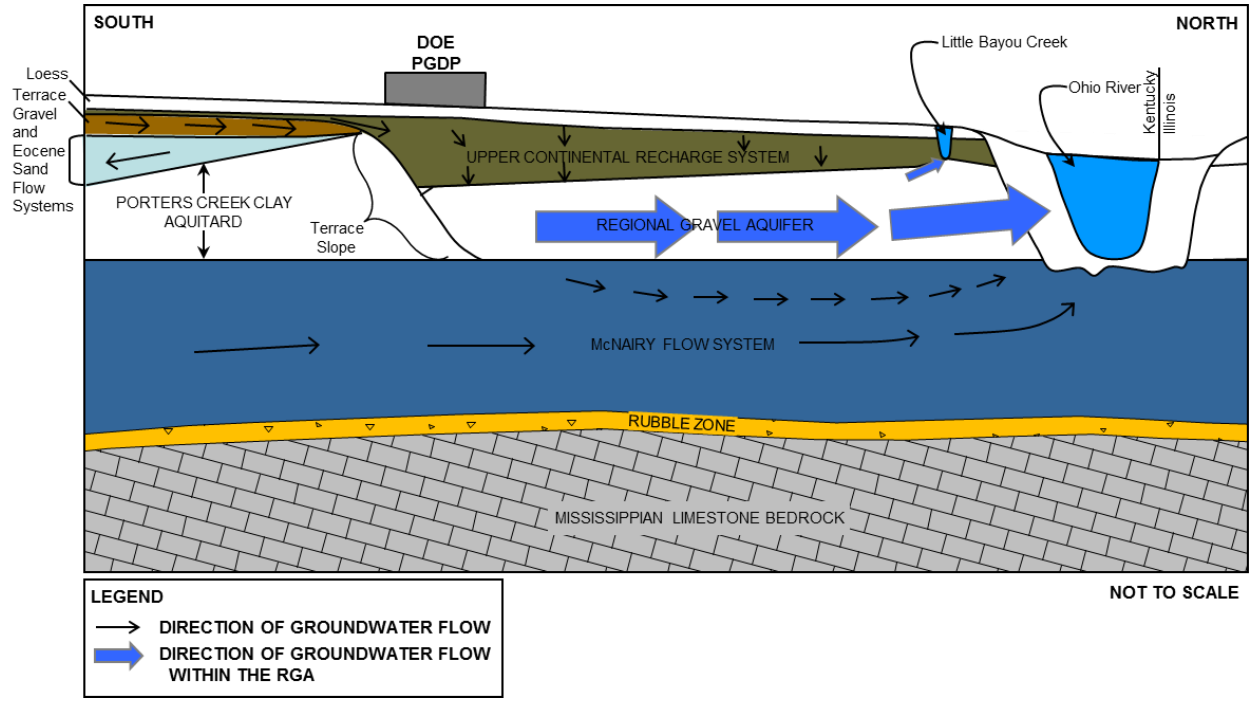


Figure 6.2. Paducah Site Groundwater Flow System and Water-Bearing Zones

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 2017d).

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).

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

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 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 (LATA Kentucky 2015); 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 2017. 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, with hyperlinks to the reports, if available. 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 2017 (January–March) Second Quarter 2017 (April–June) Third Quarter 2017 (July–September) Fouth Quarter 2017 (October–December))	0	5[b]	18	0	0	23[c]
C-746-U Landfill Wells *Quarterly Compliance Monitoring Reports*: First Quarter 2017 (January–March) Second Quarter 2017 (April–June) Third Quarter 2017 (July–September) Fourth Quarter 2017 (October–December)	0	9[b]	12	0	0	21
C-404 Landfill Wells (required by permit) *Semiannual C-404 Groundwater Monitoring Reports:* C-404 Hazardous Waste Landfill May 2017 Semiannual Groundwater Report (October 2016–March 2017) C-404 Hazardous Waste Landfill November 2017 Semiannual Groundwater Report (April 2017–September 2017)	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 2017 (Data reported January–June 2017) First Half of FY 2018 (Data reported July–December 2017)	3	0	0	0	0	3
Northeast Plume Operations and Maintenance Program *Semiannual FFA Progress Reports:* (see links above)						
Semiannual Wells	0	0	14	0	0	14
Quarterly Wells	0	0	2	0	0	2
Quarterly Optimization Wells	0	0	32	0	0	32
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	9	0	0	9
SWMU 1 Monitoring Wells *Five-Year Review* (to be reported in 2018)						
Quarterly 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	29	0	1	24
Biennial	0	4	80	1	0	85
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.
[b] Not all wells had a sufficient amount of water to obtain samples.
[c] The total number of wells where sampling is required by the permit associated with the C-746-S&T Landfills is 25; however, 2 of these wells are required by the permit only for water level measurement. The total number of analytically measured wells, therefore, is 23.

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 2017 are shown in Table 6.2.

Table 6.2. Ranges of Detected Analytes in 2017 Monitoring Well Groundwater Samples

Analyte	Range
Anions	
Bromide (µg/L)	68.6–1,240
Chloride (µg/L)	1,090–118,000*
Fluoride (µg/L)	49.0–640
Nitrate as Nitrogen (µg/L)	34.2–4,770
Sulfate (µg/L)	4,830–1,010,000
Wet Chemistry Parameters	
Alkalinity (µg/L)	53,900–186,000
Chemical Oxygen Demand (µg/L)	9,170–65,300
Cyanide (µg/L)	1.76–6.40
Dissolved Solids (µg/L)	21,400–533,000
Iodide (µg/L)	169–758
Total Organic Carbon (µg/L)	674–7,290
Total Organic Halides (µg/L)	3.38–174
Volatile Organic Compounds	
1,1,1-Trichloroethane (µg/L)	0.600–0.600
1,1,2-Trichloroethane (µg/L)	0.390–1.49
1,1-Dichloroethane (µg/L)	0.420–19.5
1,1-Dichloroethene (µg/L)	0.350–116*
Acetone (µg/L)	1.80–1.80
Benzene (µg/L)	5.21–5.21
Bromodichloromethane (µg/L)	0.870–0.870
Carbon disulfide (µg/L)	15.2–15.2
Carbon tetrachloride (µg/L)	0.370–142
Chloroform (µg/L)	0.350–374
cis-1,2-Dichloroethene (µg/L)	0.360–36,300*
Tetrachloroethene (µg/L)	0.540–2.40
Toluene (µg/L)	0.370–0.410
trans-1,2-Dichloroethene (µg/L)	0.470–9.11*
Trichloroethene (µg/L)	0.340–49,600*
Vinyl chloride (µg/L)	0.780–468
PCBs	
PCB-1242 (µg/L)	0.0432–0.0914
PCB-1248 (µg/L)	0.0540–0.131
Total PCBs (µg/L)	0.0432–0.131

Analyte	Range
Metals	
Aluminum (µg/L)	19.1–14,800
Arsenic (µg/L)	1.95–19.1
Barium (µg/L)	20.5–503
Beryllium (µg/L)	0.342–0.551
Boron (µg/L)	5.27–1,590
Cadmium (µg/L)	0.304–0.619
Calcium (µg/L)	6,390–272,000
Chromium (µg/L)	3.02–985
Cobalt (µg/L)	0.100–60.9
Copper (µg/L)	0.311–11.3
Iron (µg/L)	34.9–129,000
Iron (2+) (ug/L)	50.0-3300.0
Lead (µg/L)	0.504–8.35
Magnesium (µg/L)	3,390–58,200
Manganese (µg/L)	1.02–14,600
Mercury (µg/L)	0.067–0.292
Molybdenum (µg/L)	0.202–8.09
Nickel (µg/L)	0.502–282
Potassium (µg/L)	169–24,700
Selenium (µg/L)	2.02–4.14
Silver (µg/L)	0.313–1.11
Sodium (µg/L)	16,000–166,000
Uranium (µg/L)	0.071–8.22
Vanadium (µg/L)	3.38–22.1
Zinc (µg/L)	3.37–51.5
Arsenic, Dissolved (µg/L)	2.54–11.0
Barium, Dissolved (µg/L)	18.6–456
Chromium, Dissolved (µg/L)	3.06–39.0
Selenium, Dissolved (µg/L)	2.64–2.80
Uranium, Dissolved (µg/L)	0.068–395
Radionuclides	
Alpha activity (pCi/L)	3.22–18.5
Beta activity (pCi/L)	2.22–484
Radium-226 (pCi/L)	0.235–1.76
Radium-228 (pCi/L)	3.81–5.78
Technetium-99 (pCi/L)	14.5–15,000*
Thorium-230 (pCi/L)	0.661–1.69
Thorium-232 (pCi/L)	0.801–0.999
Uranium-234 (pCi/L)	1.32–2.24
Uranium-238 (pCi/L)	0.6561.41–1.9541

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

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. 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 2017b). 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:

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

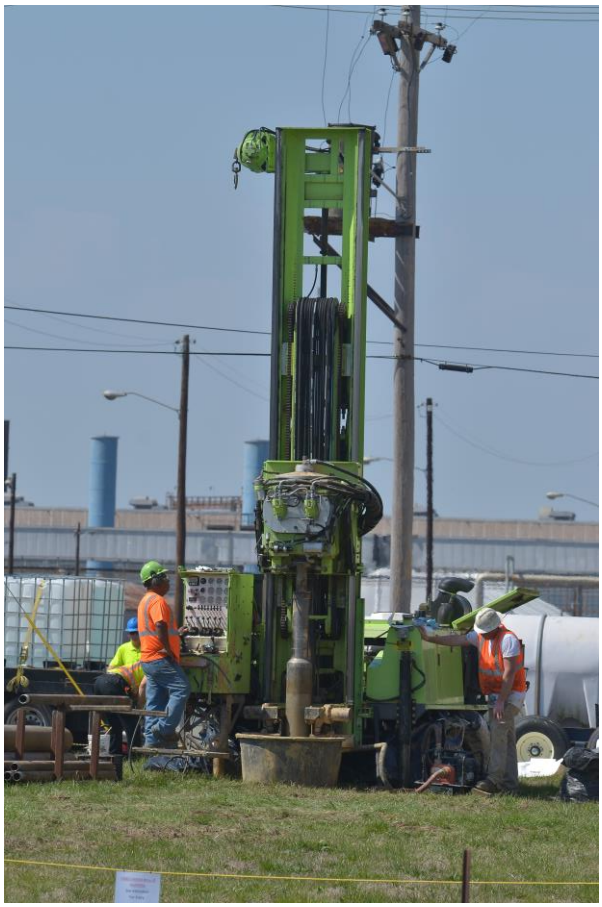


Figure 6.3 Drilling for the Northeast Plume Optimization Project

Figure 6.3 depicts drilling new extraction wells as part of the Northeast Plume Optimization Project. These wells are part of the Explanation of Significant Differences to the Northeast Plume ROD (DOE 2015b) and were operational by the end of 2017.

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 6.4. Table 6.3 lists the cumulative TCE removed from liquid VOCs and VOCs on carbon recovered through CY 2017. The graphs shown in Figures 6.5 and 6.6 illustrate the cumulative TCE removed from liquid by the Northwest Plume Groundwater Treatment System and the Northeast Plume Containment System through CY 2017.

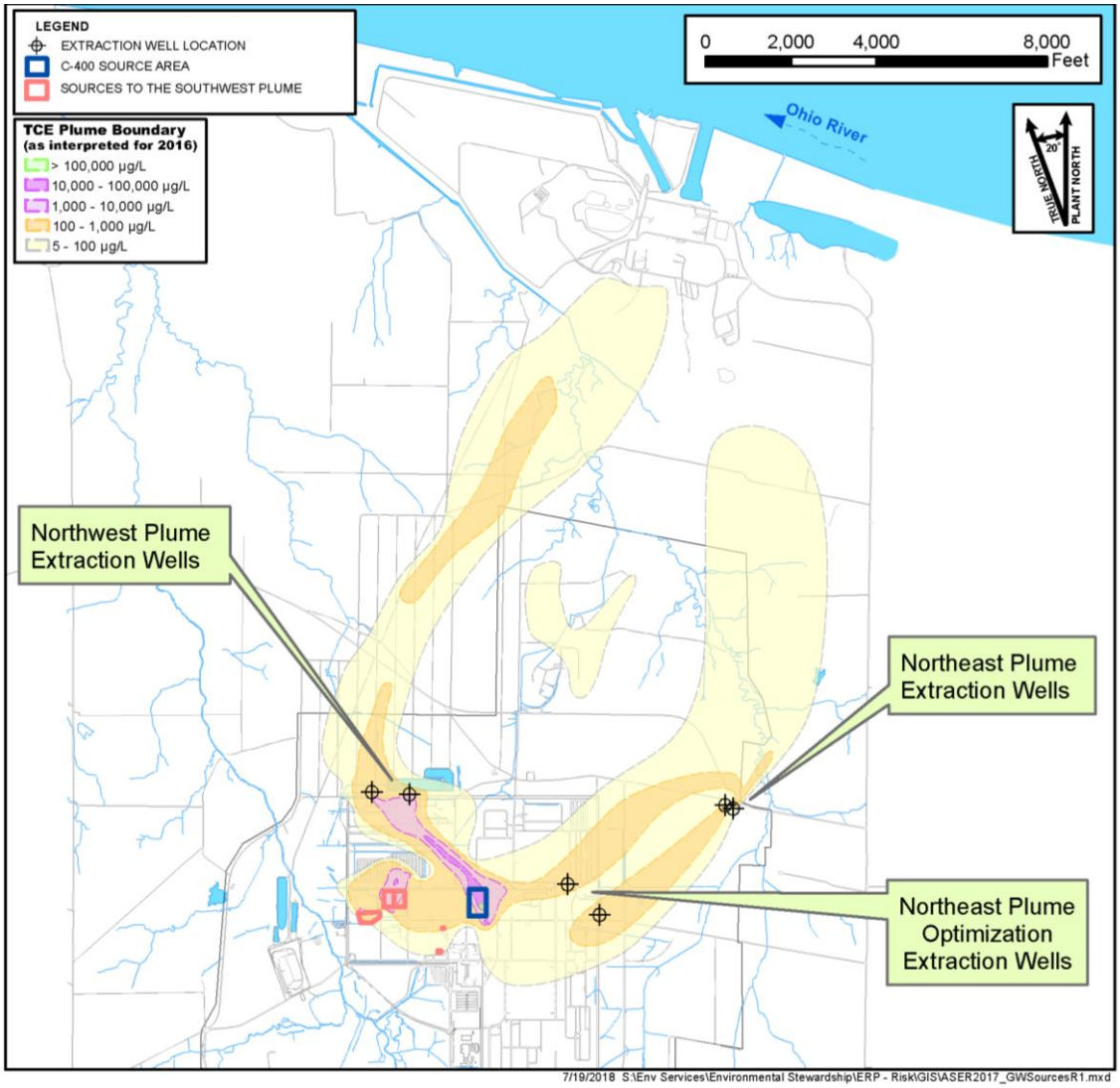
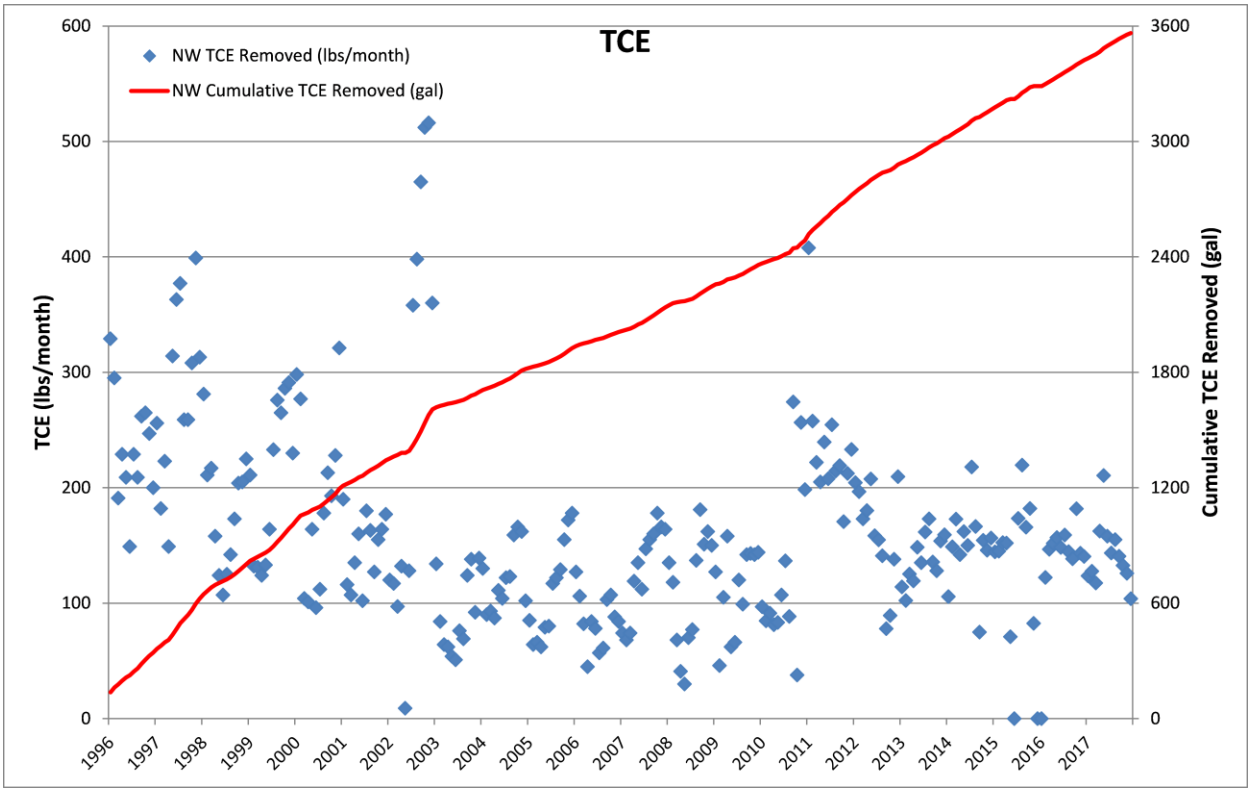


Figure 6.4. Locations of Groundwater Contamination Sources

Table 6.3. Cumulative TCE Removed at Paducah

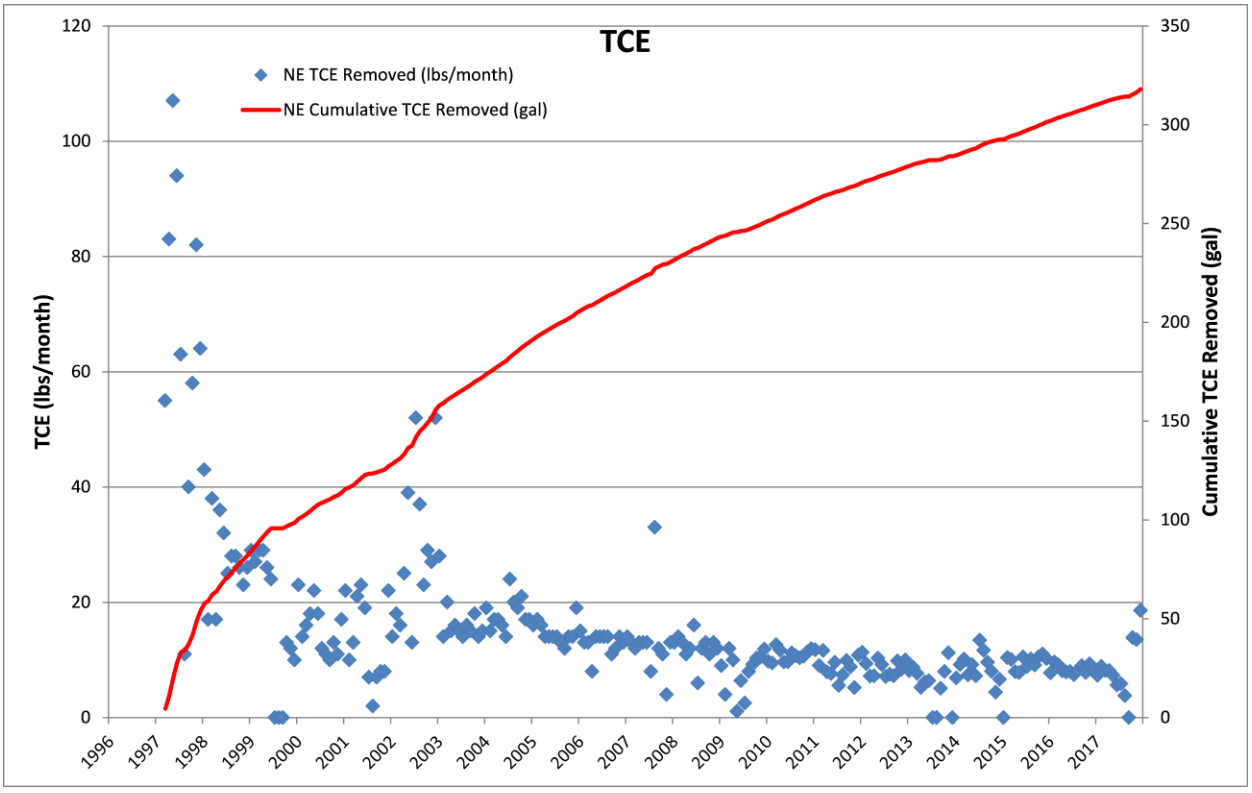
Source Area	**Cumulative TCE Removed (gal)** [a,b]
Northwest Plume Groundwater Treatment System	3,564
Northeast Plume Containment System	318
C-400 Cleaning Building Interim Remedial Action (including treatability study)	3,572
Southwest Plume Sources Remedial Action	24
LASAGNA™ treatment at Cylinder Drop Test Site	246

[a] TCE values include liquid VOCs and recovered VOCs on carbon.
[b] Cumulative through December 31, 2017. Value taken from DOE 2018d.



Source: DOE 2018d

Figure 6.5. Northwest Plume Groundwater Treatment System TCE Removed



Source: DOE 2018d

Figure 6.6. Northeast Plume Containment System TCE Removed

The Kentucky Solid Waste Facility (401 *KAR* 47:030 § 6) maximum contaminant level exceedances for 2017 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 2017

Upper Continental Recharge System	Upper RGA	Lower RGA
C-746-S and C-746-T Landfills		
No exceedances	MW369: trichloroethene MW372: beta activity, trichloroethene MW384: beta activity MW387: beta activity 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: trichloroethene MW372: beta activity, trichloroethene	MW361: trichloroethene MW364: 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 2013b). 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.

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 for the Fluor Federal Services, Inc., Paducah Deactivation Project, Paducah, Kentucky*, CP2-QA-1000;
- 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 2017, 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 2017 (DOE 2017e). 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 2017. 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 each laboratory performing analyses of samples for KPDES permit compliance to hold a Kentucky Wastewater Laboratory Certification. Four laboratories and the FFS/FRNP sampling organization held a Kentucky Wastewater Laboratory Certification in 2017. Additional information about the certification can be found at http://water.ky.gov/permitting/Pages/labcert.aspx.

7.2.4 Laboratory Audits/Sample and Data Management Organization

Laboratory audits are performed annually by the DOECAP to ensure that the laboratories are in compliance with regulations, methods, and procedures. Findings are documented and addressed by the audited laboratory through corrective actions. FFS/FRNP reviews the program's audit reports and laboratory corrective action plans for compliance with FFS/FRNP requirements on an annual basis and upon receiving a Priority 1 finding from DOECAP. Laboratories used by FRNP are participants in DOECAP. Starting in the fall of 2017, DOECAP will provide certification of environmental laboratories through third party organizations. If not in DOECAP, laboratories are audited by contractors for compliance with DOECAP/DOE Laboratory Accreditation Program requirements.

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 1998)]. 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 monthly 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, 43 packages were validated in CY 2017.

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 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 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 PGDP, 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.