Calendar Year 2016 PADUCAH GASEOUS DIFFUSION PLANT ANNUAL SITE ENVIRONMENTAL REPORT (ASER): *Student Summary*

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June 2019

Marshall County High School Ecology and Physics Students

Based on U.S. Department of Energy Paducah Gaseous Diffusion Plant Calendar Year 2016 Annual Site Environmental Report (ASER), September 2017 (FPDP-RPT-0091)

Prepared by

Kentucky Research Consortium for Energy and Environment

for

United States Department of Energy Portsmouth/Paducah Project Office

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Cover Photo: Tupelo Swamp located in the West Kentucky Wildlife Management Area in the vicinity of the Department of Energy's Paducah Gaseous Diffusion Plant Reservation.

Contents

LIST OF FIGURES

LIST OF TABLES

MESSAGE FROM THE STUDENTS

Dear Reader,

We hope that our summary Paducah Gaseous Diffusion Plant environmental report, *CALENDAR YEAR 2016 ANNUAL SITE ENVIRONMENTAL REPORT (ASER): Student Summary Report,* helps you understand what industrial operations related to uranium enrichment occurred at the U.S. Department of Energy's (DOE) Gaseous Diffusion Plant (PGDP), how past operations impacted the environment, what the DOE is doing to address environmental impacts, and what monitoring indicates about current environmental conditions. Our MCHS Ecology and Physics classes are thankful to have been chosen to learn about the history of the PGDP, uranium enrichment as a large-scale industrial operation, Western Kentucky's history and role in the Cold War, historical environmental impacts at the PGDP, and work being conducted to address and remediate environmental impacts that have occurred during the plant's operations.

Sincerely,

MCHS 2018-19 Ecology and Physics Students

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#Marshall Strong

MESSAGE FROM THE DEPARTMENT OF ENERGY

The U.S. Department of Energy (DOE) conducts comprehensive environmental monitoring at the Paducah Gaseous Diffusion Plant (PGDP) site and nearby areas to ensure protection of human health and the environment. Each year environmental monitoring data is summarized and presented by the PGDP site in a comprehensive annual environmental report. During the 2018-19 school year, Marshall County (Kentucky) High School AP Ecology and Advanced Placement (AP) Science students participated in classroom and field activities related to the DOE's *Paducah Site Environmental Report for Calendar Year 2016 (2016 ASER)*. The 2016 ASER was published and distributed by the DOE during calendar year 2017. Students compiled the results of their 2016 ASER review in the document *CALENDAR YEAR 2016 ANNUAL SITE ENVIRONMENTAL REPORT (ASER): Student Summary Report*.

Environmental work at DOE's facilities is technically complex and challenging. The scale of the PGDP industrial complex, its infrastructure and impacts on the surface and subsurface environment magnify the technical complexities faced by the DOE in its management and cleanup efforts. Beginning in 2014 DOE's challenges increased with the shutdown of PGDP's enrichment operations and the preparation for the dismantling of enrichment process facilities.

The annual ASER Student Summary Report is important to DOE as a tool to explain the comprehensive PGDP environmental monitoring and remediation programs to stakeholders. PGDP environmental data collected from soil, surface water, sediment, air, and groundwater during 2016 indicated that the site is in compliance with regulatory and human health standards and is actively pursuing the remediation of on-site sources of environmental contamination while concurrently pursuing the deactivation and dismantlement of the site's industrial facilities and infrastructure.

The PGDP site sincerely appreciates the work of the students and staff at Marshall County High School in the production of the *CALENDAR YEAR 2016 ANNUAL SITE ENVIRONMENTAL REPORT (ASER): Student Summary Report*. On behalf of the entire Department of Energy, we congratulate each of you for your effort, enthusiasm, and willingness to support DOE with this project.

We hope that you enjoy the *CALENDAR YEAR 2016 ANNUAL SITE ENVIRONMENTAL REPORT (ASER): Student Summary Report.*

Sincerely,

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ACRONYMS

AEC	Atomic Energy Commission
ASER	Annual Site Environmental Report
bgs	below ground surface
BWCS	B&W Conversion Services, LLC
CAA	Clean Air Act
CAB	Paducah Citizens Advisory Board
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
CY	calendar year
D&D	decontamination and decommissioning
DNAPL	dense non-aqueous-phase liquid
DOE	United States Department of Energy
DOECAP	Department of Energy Consolidated Audit Program
EIC	Environmental Information Center
EIS	environmental impact statement
EM	environmental management
EMP	Environmental Monitoring Plan
EMS	Environmental Management System
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
FFA	Federal Facility Agreement
FY	fiscal year
GDP	gaseous diffusion plant
GHG	greenhouse gas
GW	Groundwater
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
LATA	Los Alamos Technical Associates Environmental Services of Kentucky, LLC
LLW	low-level radioactive waste
MCL	maximum contaminant level
MEI	maximum exposed individual
MW	monitoring well
ND	not detected
NEPA	National Environmental Policy Act
NEPCS	Northeast Plume Containment System
NFA	no further action
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
NWPGS	Northwest Plume Groundwater System
OREIS	Oak Ridge Environmental Information System
PGDP	Paducah Gaseous Diffusion Plant
PEGASIS	Paducah Environmental Geographic and Spatial Information System

PPPO	Portsmouth/Paducah Project Office
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
FFS	focused feasibility study
RGA	Regional Gravel Aquifer
ROD	record of decision
SARA	Superfund Amendments and Reauthorization Act
SMP	Site Management Plan
SSP	site sustainability plan
SST	Swift & Staley Team
SWMU	solid waste management unit
TCE	trichloroethylene
TLD	thermoluminescent dosimeter
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
UCRS	Upper Continental Recharge System
UDS	Uranium Disposition Services, LLC
USEC	United States Enrichment Corporation
UST	underground storage tank
VOC	volatile organic compound
WKWMA	West Kentucky Wildlife Management Area
WMP	Watershed Monitoring Plan

1.0 Introduction

The purpose of this Annual Site Environmental Report is to summarize United States Department of Energy (DOE) Calendar Year 2016 environmental management activities at the Paducah Gaseous Diffusion Plant (PGDP) and its surroundings. Environmental management activities include effluent monitoring, environmental surveillance, and environmental compliance. Additionally, the report is intended to highlight significant site environmental program efforts. DOE implements programs to measure impacts that operations have on the environment or the public and reports on those programs annually. Surveillance under DOE programs includes analyses of surface water, groundwater, sediment, ambient air, and direct radiation. DOE conducts PGDP environmental management activities under the requirements of DOE Order 231.1B (Environment, Safety, and Health Reporting) as well as additional DOE Orders, Federal and State requirements (Chapter 2).

The main goals of DOE's environmental management at the PGDP are to keep visitors, workers, communities, wildlife and the environment safe from exposure to and impacts from harmful chemicals and radiation related to the site and to maintain full compliance with current environmental regulations.

There are 2 types of environmental monitoring at the PGDP: effluent monitoring and environmental surveillance. Effluent monitoring is the collection and analysis of samples representing liquid and gaseous discharges to the environment. Environmental Surveillance is the collection and analysis of samples of representative of PGDP and vicinity air, surface water, soil, groundwater, and sediment. In order to address and remediate environmental impacts, effluent monitoring and environmental surveillance are conducted. Effluent and environmental samples are collected, tested for radioactivity, chemical constituents and physical properties. Sample results are then evaluated relative to compliance with regulations that address environmental impacts and safety.

During calendar year 2016 several prime contractors worked at the PGDP to support DOE's site missions including: BWXT Conversion Services, LLC (BWCS) operated depleted uranium hexafluoride recovery facilities; Swift & Staley Inc. (SST) managed and operated PGDP technical services; and Fluor Federal Services, Inc. (FFS)/Fluor Paducah Deactivation Project (FPDP) managed PGDP environmental and deactivation activities.

1.1 Site Background

The Paducah Gaseous Diffusion Plant (PGDP) is a retired uranium enrichment facility located west of Paducah, Kentucky (Figure 1.1). The PGDP is owned by the United States Department of Energy (DOE), operated and managed by DOE prime contractors. The PGDP enrichment plant was constructed and began operations in the early 1950's to support the nation's Cold War nuclear efforts.

Enrichment operations at PGDP were carried out on an industrial site of more than one square mile. The focus of enrichment operations were large 'Process' buildings where the process of uranium enrichment occurred. Upon completion in the early 1950's the process buildings were among the largest buildings constructed in the world.

To support enrichment operations, the industrial site contains facilities required for material delivery, preparation, material storage, electrical distribution and enrichment process components, water treatment, process system cooling, fire suppression, steam generation, as well as sanitary and industrial waste disposal (Figure 1.2; Figure 1.3).

The PGDP's enrichment process consumed immense amounts of electricity which exceeded the daily electrical consumption of New York City (Paducah Sun-Democrat, April 17, 1955, Inside the A-Plant, page B-1). The site's electrical demands required its own source of electrical power that was supplied through construction and operation of the Tennessee Valley Authority's Shawnee Steam Plant, immediately north of the PGDP on the Ohio River and the construction and operation of the Electrical Energy Incorporated Joppa Steam Plant in southern Illinois.

Historical industrial operations at the PGDP created industrial process waste that contained radioactive and hazardous materials. Over the course of PGDP operations, the routine handling, storage and disposal of radioactive and hazardous materials resulted in contamination of soil, surface water and groundwater which DOE now actively monitors and remediates. Since 1988 and the discovery of the radionuclide technetium-99 (Tc-99) in residential water wells near the site, DOE has been investigating, monitoring and remediating the origin, extent and impacts of PGDP's uranium enrichment operations on workers, the public and the environment.

1.2 Site Location

The PGDP is located west of Paducah, Kentucky (Figure 1.1). The PGDP industrial site occupies one square mile of a 3,556-acre DOE Reservation approximately 10 miles west of Paducah, and 3.0 miles south of the Ohio River (Figure 1.2). Of the 3,556 acres: 837 acres are within a fenced security area (industrial site), 600 outside of it, 133 are in acquired easements, and 1,986 surrounding acres are licensed to the Commonwealth of Kentucky as part of the West Kentucky Wildlife Management Area (WKWMA).

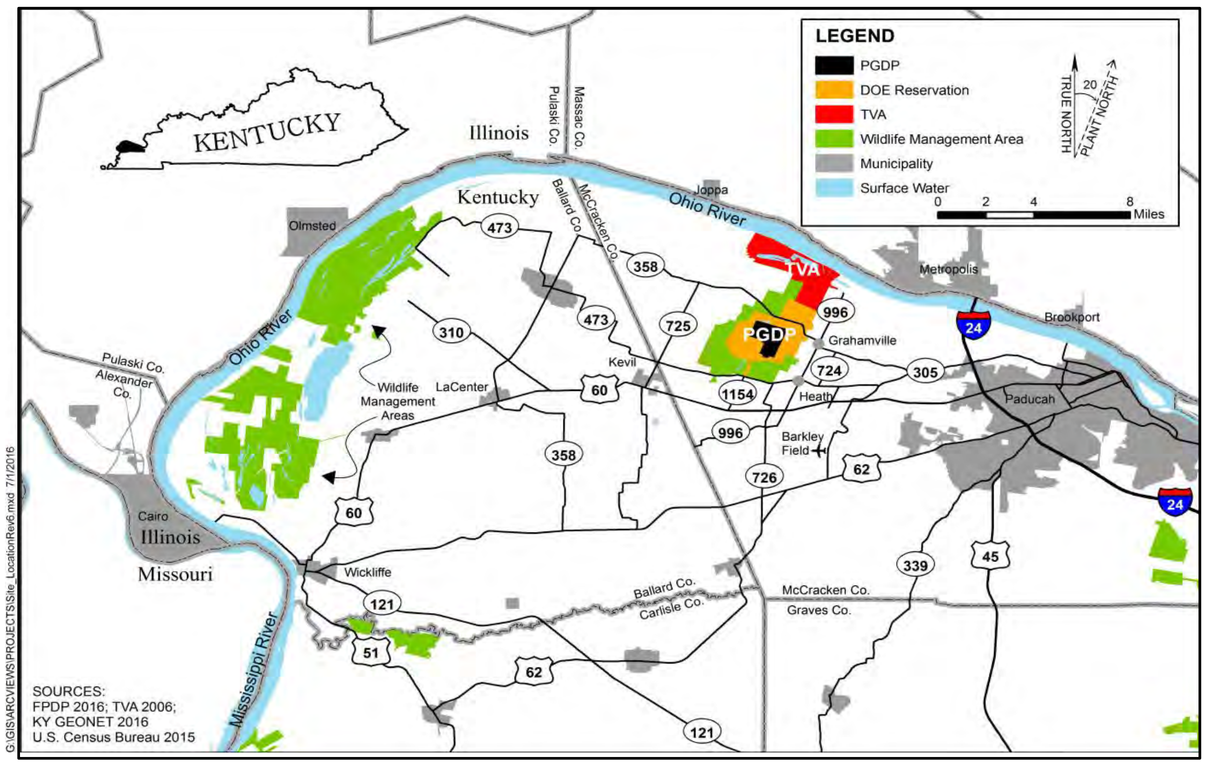


Figure 1.1 Location of the Paducah Site

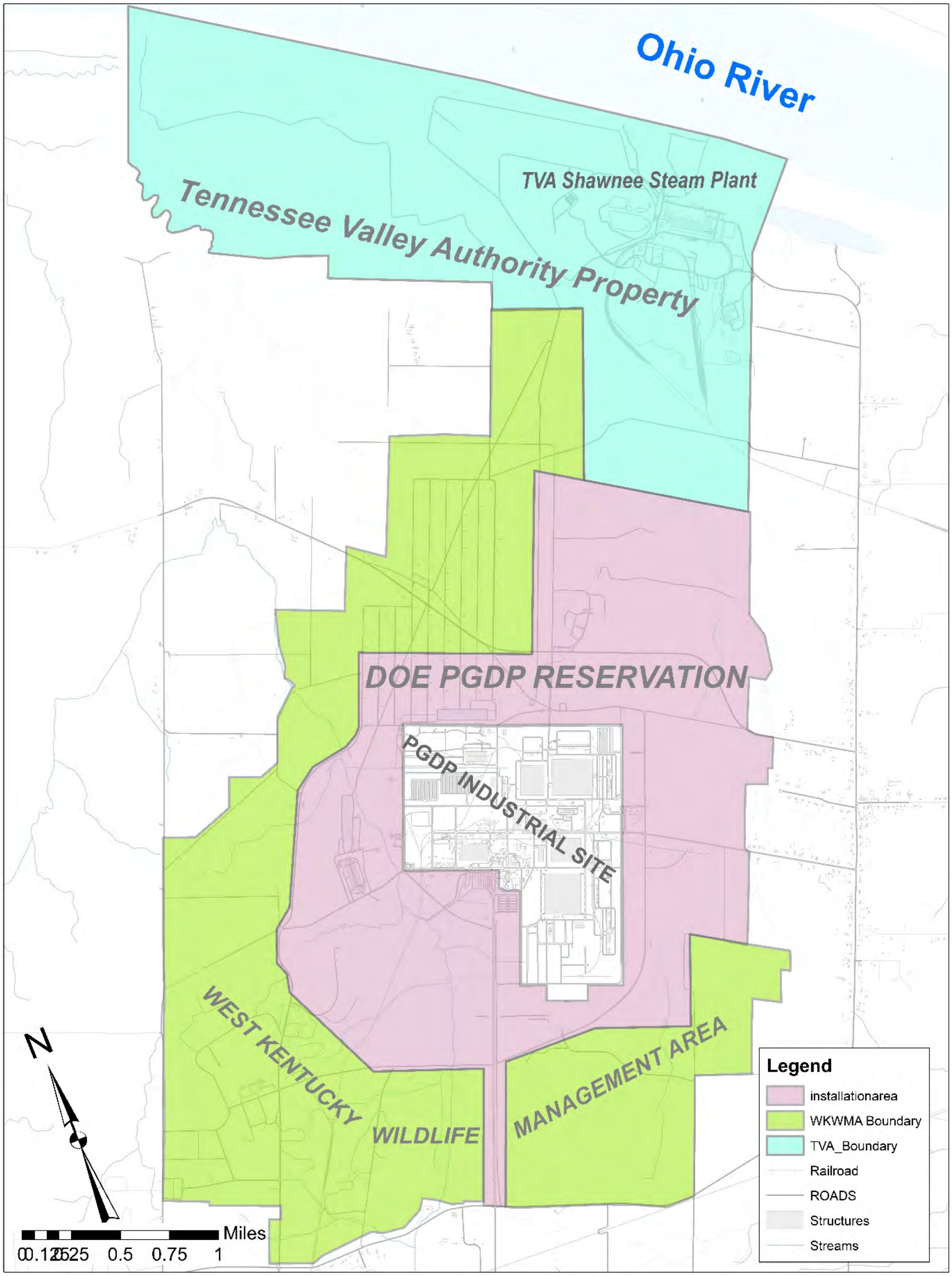


Figure 1.2. Property Surrounding the PGDP.

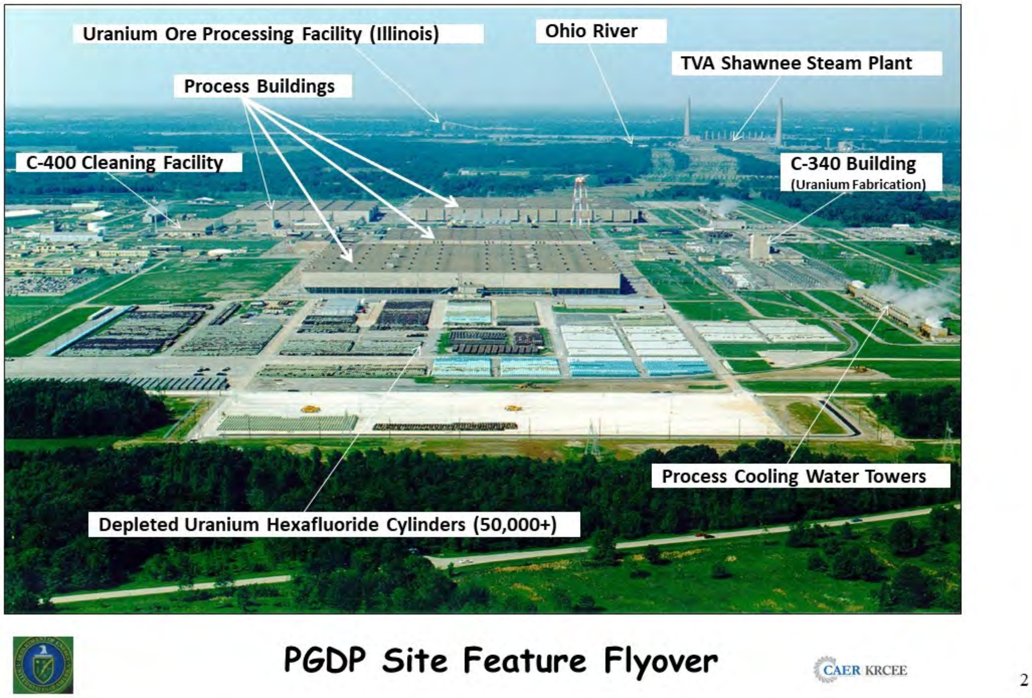


Figure 1.3 Flyover view of the PGDP Industrial Site and associated facilities (circa 2006).

(Currently, the C-340 building has been demolished and the number of depleted Uranium Hexafluoride cylinders has increased to approximately 53,000.)

During World War II portions of the DOE Reservation and WKWMA were operated by Atlas Powder Company as the Kentucky Ordnance Works (KOW). KOW was the nation's largest producer and supplier of trinitrotoluene (TNT) for the U.S. war effort.

1.3 Demographic Information

Based on the 2010 U.S. census, the population of McCracken County, Kentucky, including the city of Paducah, is approximately 65,000. The population within a 50-mile radius of the Paducah Site is approximately 534,000 and within a 10 mile radius of PGDP the population is 89,000. The rural communities of Heath and Grahamville are three (3) miles east and west of the PGDP, respectively. The community of Kevil is approximately three (3) miles southwest of the PGDP.

1.4 General Environmental Setting

The WKWMA and non-industrial portions of the DOE Reservation consist of woodlands, meadows, wetlands and cultivated fields. WKWMA is popular for deer and waterfowl hunting, trapping, hunting-dog training, hunting-dog competition, horseback riding, fishing and general outdoor recreation.

1.4.1 Climate

The Paducah Plant and surrounding DOE Reservation are located in the eastern United States humid continental zone where summers are warm (July temperatures average 79^{o} F) and winters are moderately cold (January temperatures average 35^0 F). Precipitation averages 49 inches per year and prevailing wind is from the south-southwest at 10 miles per hour.

1.4.2 Surface Water Drainage

The Paducah Plant is located approximately 3.0 miles south of the Ohio River in the lower Ohio River Basin. The Cumberland and Tennessee Rivers join the Ohio River approximately 15 miles upstream of the PGDP. The confluence of the Ohio and Mississippi Rivers is about 35 (river) miles downstream of the PGDP.

The PGDP DOE Reservation occupies portions of Bayou Creek and Little Bayou Creek watersheds. Water in the PGDP industrial area enters drainage ditches that convey the water through permitted surface water outfalls to Bayou and Little Bayou Creeks. Surface water from the east side of the PGDP industrial site flows east-northeast into ephemeral upstream portions of Little Bayou Creek. Surface water from the west side of the PGDP industrial site flows west-northwest into perennial Bayou Creek. Bayou and Little Bayou Creeks converge 3 miles north of the PGDP industrial site before discharging to the Ohio River.

1.4.3 Wetlands

More than 1,100 separate wetlands, totaling over 1,600 acres, are found in the 12,000 acres around the PGDP (COE 1994). More than 60% of the total wetland area is forested. As part of activities associated with the 2014 PGDP Annual Site Environmental Report: Student Summary Project, MCHS students provided hands-on assistance to the University of Kentucky and the WKWMA in the assessment and delineation of amphibian wetland habitat in 16 tracts (Figure 1.4) surrounding the PGDP documented in the 2016 publication Amphibian Habitat Assessment at the Paducah Gaseous Diffusion Plant and the West Kentucky Wildlife Management Area (Price, 2016).

1.4.4 Soils and Hydrogeology

Naturally occurring soils in the vicinity of the Paducah Plant are predominantly silt loam soils that are poorly drained, acidic, and have little organic content. Groundwater from the aquifer that underlies portions of the PGDP industrial site is utilized extensively for agriculture and domestic purposes in areas that have not been impacted by PGDP activities. The local groundwater flow system and aquifer at the Paducah Site are described in Chapter 6.

1.4.5 Vegetation

Much of the vegetation in the vicinity of the PGDP has been impacted by human activity and is now old field succession. Open grassland areas are managed by the WKWMA and are burned periodically to promote native species growth. Some open areas of the WKWMA are cultivated with corn, soybeans, milo and millet to support wildlife forage. Field scrub-shrub communities consist of sun tolerant wooded species. Upland mixed hardwood forests contain a variety of upland and transitional species (CH2M HILL 1992; CH2M HILL 1991).

1.4.6 Wildlife

Wildlife species present in the vicinity of the PGDP are indigenous to hardwood forest, scrub-shrub, open grassland and wetland communities. Migratory waterfowl seasonally utilize the wetlands and open areas surrounding the PGDP. Many types of sunfish and shiners inhabit the creeks and open water bodies. Amphibian species are common in natural and man-made wetlands as well as surface waterways surrounding the PGDP. During calendar year 2016, MCHS students continued to support the UK and WKWMA in the identification and enumeration of amphibian species in tracts surrounding the PGDP (Figure 1.4).

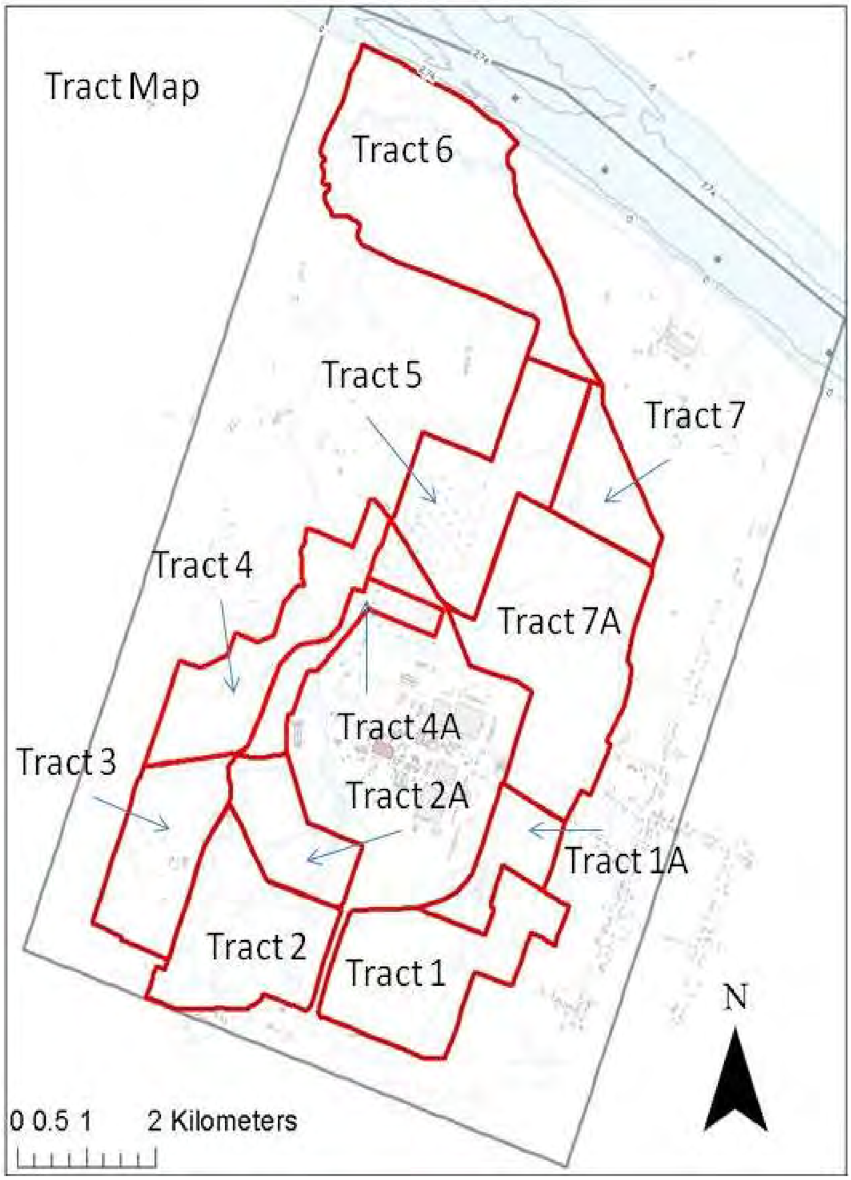


Figure 1.4. Wetlands Assessment Tracts

1.4.7 Threatened and Endangered Species

A threatened and endangered species investigation identified federally listed, proposed, or candidate species potentially occurring in habitats at or near the Paducah Site (COE 1994). Eleven of these species (Table 1.1) are listed as "endangered", one is "threatened" and one is proposed for listing under the Endangered Species Act of 1973. None of candidate species have been found on the DOE reservation.

Table 1.1 Threatened and Endangered Species Potentially Present in the vicinity of the PGDP

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

1.5 Site Mission

DOE created the Portsmouth/Paducah Project Office (PPPO) to provide leadership for environmental management activities at the Portsmouth, Ohio and Paducah, Kentucky Gaseous Diffusion Plants (http://energy.gov/pppo/pppo-mission).

The main goals of the PPPO's PGDP activities are to protect human health and the environment, accelerate the site environmental cleanup, eliminate potential environmental threats, reduce DOE's footprint, and reduce life-cycle site management costs. In order to achieve these goals DOE and its prime contractors conduct ongoing environmental remediation, waste management, decontamination and decommission (D&D) activities, and conversion of the depleted Uranium Hexafluoride (DUF6).

1.6 Primary Operations and Activities at the Paducah Site

Two major programs are in place to help DOE oversee the Paducah site: 1) the Environmental Management (EM) Program; and 2) Uranium Program. The EM program includes Environmental Restoration, Facility Stabilization, Deactivation, Decontamination and Decommissioning, Infrastructure Optimization and Waste Management Projects.

The Uranium Program manages storage, handling and disposition of DOE's depleted Uranium Hexafluoride (DUF6) inventory at the PGDP including the operation of PGDP's DUF6 Conversion Facility. The Conversion Facility separates DUF6 to a stable oxide of uranium and hydrofluoric acid. The stable uranium oxide minimizes potential waste disposal or re-use impacts. Hydrofluoric acid is sold to industry for re-use.

The Environmental Restoration Project (ER) manages environmental investigations and responses to releases from past site operations and operates to ensure that human health and the environment are protected. The ER is conducted in accordance with a Federal Facilities Agreement (FFA) between DOE, the U.S. Environmental Protection Agency (EPA) and the Commonwealth of Kentucky. The FFA is in place to help with the management and State and Federal environmental law compliance.

The Waste Management Program is in place to make sure that waste is disposed of properly in a manner protective of human health and the environment. The D&D Project was put in place to eliminate unused facilities in a manner protective of human health and the environment.

The environmental monitoring summarized in this report supports DOE's PGDP Programs and Projects.

2.0 Environmental Regulations & Compliance

The main goals of DOE's environmental management at the PGDP are to: 1) Keep visitors, workers, communities, wildlife and the environment safe from potential exposure to and impacts from harmful chemicals and radiation related to the site; and 2) To maintain full compliance with current environmental regulations. The Federal and State laws, regulations, and DOE Orders and internal environmental management requirements are discussed in this section. During calendar year 2016, DOE and its prime contractors conducted extensive environmental management and compliance activities at the PGDP as discussed in the following sections of this chapter.

The U.S EPA, Region 4 (EPA), and the Kentucky Department for Environmental Protection (KDEP) are the principal regulatory agencies that oversee environmental activities at the PGDP. The agencies facilitate the following: issuing permits, reviewing compliance reports, reviewing and providing input on remediation strategies, participating in joint monitoring programs, inspecting facilities and operations, and overseeing compliance with applicable laws and regulations.

EPA develops, promulgates and enforces environmental protection regulations and technology standards pursuant to statutes passed by the U.S. Congress. EPA regulatory authority is delegated to KDEP when Kentucky regulatory program criteria meet or exceed EPA requirements.

2.1 Environmental Restoration and Waste Management

2.1.1 Comprehensive Environmental Response, Compensation, and Liability Act

The Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) became law in 1980 in order to address sites containing hazardous wastes. CERCLA established liability for individuals and businesses responsible for a hazardous waste site contamination. Also known as 'Superfund', CERCLA established a trust fund to clean up abandoned sites and provisioned the trust fund thru taxes on chemicals and hazardous materials. EPA has regulatory authority for CERCLA.

The DOE and EPA Region 4 manage PGDP's environmental cleanup activities through an Administrative Consent Order (ACO) required under Sections 104 and 106 of CERCLA. The ACO was put in place in response to the off-site groundwater contamination detected near the Paducah site in July 1988.

On May 31, 1994 the PGDP was placed on the EPA National Priorities List (NPL). The NPL identifies sites with the highest priority for site remediation based on potential impacts to human health and the environment. EPA uses the Hazard Ranking System to determine sites that should be included on the NPL.

CERCLA Section 120 requires federal agencies responsible for an NPL site to enter into a Federal Facilities Agreement (FFA) with EPA. The FFA coordinates CERCLA remedial action requirements with Resource Conservation and Recovery Act (RCRA) regulatory requirements. RCRA regulatory requirements are the responsibility of the State and administered through KDEP. The PGDP FFA has been in place since 1998 when DOE, EPA, and KDEP agreed to terminate the CERCLA ACO and manage the PGDP's ACO environmental decision making under the FFA.

DOE submits an annual FFA Site Management Plan to the EPA and KDEP. The Plan summarizes pending remediation and monitoring work, outlines remedial priorities, and contains schedules for completing future work. Significant enforceable milestones required under CERCLA and the FFA for 2016 are listed in Table 2.1.

During 2016, the FFA parties suspended efforts to finalize the FY 2016 Site Management Plan in order to integrate components of DOE's sitewide cleanup plan. An integrated FY 2017 Site Management Plan was submitted to EPA and KDEP for review and approval.

2.1.2 Superfund Amendments and Reauthorization Act

CERCLA was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA). The Act placed EPA's experience administering the complex Superfund program into law, put increased focus on human health problems posed by hazardous waste sites, and encouraged greater citizen participation in making decisions on how sites should be cleaned up.

Table 2.1 CY 2016 CERCLA and FFA Significant Milestone Requirements for PGDP

Document/Activity	**Date Due**	**Date Completed**
Disposition of Inactive Facilities Decontamination and Decommissioning Operable Unit Completion Notification Letter (C-410) D1	4/11/2016	4/11/2016
Soils Operable Unit SWMU 27 Removal Notification D1	6/22/2016	6/21/2016
Burial Grounds Operable Unit SWMU 4 Remedial Investigation Report Addendum D1	8/4/2016	8/2/2016
Southwest Plume Sources SWMU 1 (Soil Mixing) Remedial Action Completion Report D1	9/2/2016	9/1/2016
Groundwater Operable Unit Northeast Plume Optimization Field Start	9/27/2016	9/27/2016
Site Management Plan for FY 2017 D1	11/15/2016	11/15/2016

*Groundwater Operable Unit C-400 Phase IIb Revised Proposed Plan milestone date was revised beyond 2016. New dates for completion followed resolution of dispute and will be established using FFA schedule.

2.1.3 Resource Conservation and Recovery Act

Regulatory standards for 'cradle to grave' characterization, treatment, storage and disposal of solid and hazardous wastes are established by the Resource Conservation and Recovery Act (RCRA). Owners and operators generating hazardous waste are required to obtain permits for the handling, treatment, storage and disposal of hazardous wastes.

The PGDP generates solid, hazardous, and mixed waste (mixed waste = hazardous waste with radioactivity) and operates three permitted hazardous waste storage and treatment facilities: 1) C-733 Waste Oil and Chemical Storage Facility; 2) C-746-Q Hazardous and Low-level Mixed Waste Storage Building; and 3) C-752-A Toxic Substances Control Act (TSCA) Storage Building. The C-404 Landfill which contains hazardous and radioactive waste from enrichment process activities has been closed and is managed under a RCRA permit. FPDP submitted a partial closure certification to the Kentucky Division of Waste Management (KDWM) which was approved during FY 2016.

2.1.4 Resource Conservation and Recovery Act Hazardous Waste Permit

Part A and Part B of RCRA permit applications for storage and treatment of hazardous wastes at PGDP were submitted for the Paducah Site in the late 1980s. The current hazardous waste management facility permit was issued to DOE in July 2015 (FY 2016). Amendments to address air releases from hazardous waste facilities were submitted during FY 2016 but were not formally included in the permit by the close of the Fiscal Year. There were no Notices of Violation issued for the Hazardous Waste Facility Permit during CY 2016.

2.1.5 Federal Facility Compliance Act - Site Treatment Plan

Figure 2.1 PGDP personnel in protective gear conduct waste sampling

The Federal Facility Compliance Act (FFCA) was enacted in October 1992. The FFCA waived immunity from fines and penalties for federal facilities for violations of RCRA hazardous waste management. Mixed waste contains hazardous waste and radioactive waste components and the FFCA requires development of site treatment plans (STPs) for the treatment of mixed waste generated at the PGDP. In September 1997 the DOE and KDEP entered and Agreed Order/STP to manage PGDP's mixed waste and facilitate compliance with the FFCA.

The 1997 Agreed Order/STP required implementation of a Waste Minimization – Pollution Prevention Awareness Program to minimize generation of hazardous and mixed wastes. The Awareness Program includes the following goals: 1) Reduce quantity at sources; 2) Treat waste water on site to meet discharge criteria; 3) Drain, dry, decant liquids from wastes; 4) Segregate, sort, consolidate and reduce waste volumes; and 5) Re-use or recycling of waste-bearing materials.

During CY 2016 no mixed low-level waste was added to the PGDP STP.

2.1.6 National Environment Policy Act

The evaluation of the potential environmental impacts of proposed federal activities is required by the National Environmental Policy Act (NEPA) under DOE's NEPA Implementing Procedures (10 CFR Part 1021) and Council on Environmental Quality Regulations (40 CFR Parts 1500-1508). PGDP evaluates proposed non-CERCLA actions and determines if they require preparation of an Environmental Impact Statement (EIS), Environmental Assessment (EA), or receive a categorical exclusion from EIS or EA preparation.

The DOE Paducah Site Office and the PPPO NEPA compliance officer approved and monitored the internal applications of previously approved categorical exclusion determinations during CY 2016. The exclusion applications and approvals addressed many minor PGDP activities including demolition of process support buildings (Figure 2.2), routine maintenance, small-scale facility modifications, site characterization, facility deactivation, and utility consolidation. The CERCLA process incorporates documentation of NEPA considerations into the planning process for ongoing CERCLA environmental activities.

Figure 2.2 Demolition of C-212 Office Building

2.1.7 Toxic Substances Control Act

The Toxic Substances Control Act (TSCA) was enacted in 1976 to ensure that information on the production, use, environmental and health effects of chemical substances or mixtures is obtained by the EPA and that EPA has the information to regulate the substances and mixtures. Many familiar substances with potential environmental and health impacts are utilized and handled at the PGDP including polychlorinated biphenyls (PCBs), chlorofluorocarbons, asbestos and lead.

The PGDP complies with PCB regulations (40 CFR Part 761) under a TSCA Uranium Enrichment Federal Facilities Compliance Agreement. Major PCB-related activities conducted at the PGDP are documented in a Uranium Enrichment Toxic Substances Control Act Compliance Agreement Annual Report.

2.2 Radiation Protection

DOE is provided authority for Radiation Protection of the Public under the Atomic Energy Act of 1954 (AEA). DOE's authority for Radiation Protection of the Environment is established by DOE Order 458.1 and its authority for Radioactive Waste Management is established by DOE Order 435.1. Under the AEA and DOE Orders, DOE establishes the requirements for protection of the public and the environment against any undue risk from radiation associated with activities handling and disposing of radioactive materials.

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

PGDP prime contractor FPDP has established an Environmental Radiation Protection Program (ERPP) to comply with DOE Order 458.1. The goals of the ERPP are to: 1) conduct radiological activities so that exposure to members of the public is maintained within the dose limits established by the Order; 2) control the radiological clearance of real and personal property containing residual radioactivity; 3) ensure that potential radiation exposures to members of the public are As Low As Reasonably Achievable (ALARA); 4) monitor routine and non-routine radiological releases and to assess the radiation dose to members of the public; and 5) provide protection of the environment from the effects of radiation and radioactive material.

2.2.2 DOE Order 435.1, Radioactive Waste Management

The PGDP manages low-level, high-level and transuranic waste in compliance with DOE Order 435.1. Order 435.1 establishes the need for a determination of 'Authorized Limits' for material containing residual radioactivity in DOE waste disposal facilities, on DOE property and in materials released to the public or industry. Authorized limits are intended to ensure that any reasonable exposure to material containing residual radioactivity would result in a dose below levels established by the Order.

2.3 AIR QUALITY AND PROTECTION

2.3.1 Clean Air Act

The PGDP complies with Federal and Commonwealth of Kentucky rules by implementing the Clean Air Act (CAA) and its amendments. EPA Region 4 and/or the Kentucky Division for Air Quality (KDAQ) have authority for enforcing compliance with the CAA. There are 3 air emission permits that the PGDP complies with: 1) the DUF6 Conversion Facility Conditional Major Air Permit; 2) CERCLA; and 3) Deactivation Title V Air Permit.

The Title V permit includes 38 emission units including boilers, process stacks, fugitive emissions sources, process cooling systems, and emergency power generators. The Northwest Plume Groundwater System (NWPGS) and Northeast Plume Containment System (NEPCS) facilities are permitted air emission sources at the PGDP related to ongoing containment and treatment of contaminated groundwater. During CY 2016, the PGDP did not receive any CAA notices of violation.

2.3.2 National Emission Standards for Hazardous Air Pollutants Program

The National Emission Standards for Hazardous Air Pollutants Program addresses air emission releases of radionuclides and requires the PGDP to operate under an EPA-approved release management plan. Potential radionuclide air release sources at the PGDP were PGDP deactivation activities, the DUF6 Conversion Facility, NEPCS, NWPGS, fugitive and diffuse sources. DOE conducted ambient air monitoring at nine solar-powered locations surrounding the PGDP to verify a low emission rates for radionuclides in off-site air.

2.3.3 Pollutants and Sources Subject to Regulation

Releases of carbon monoxide, nitrogen oxides, sulfur oxides exceeding 100 tons/year and hydrogen fluoride exceeding 10 tons/year are possible from activities conducted at the PGDP. Potential pollutant emission sources at PGDP include the Deactivation Project and the DUF6 Conversion facility.

The PGDP DUF6 conversion facility has the potential to emit more than 10 tons of hydrogen fluoride per year but its emissions are managed to release no more than 9 tons per year. The DUF6 conversion facility and other facilities and activities with the potential to release more than 10 tons/year of any hazardous air pollutant or 25 tons/year of any combination of hazardous air pollutants are operated under air permits.

2.3.4 Stratospheric Ozone Protection

Clean Air Act Title VI Stratospheric Ozone Protection provisions require reporting and management of ozone-depleting substances. DOE operates refrigeration units containing less than 50 pounds of ozone-depleting substances and an extensive cooling system containing 6.3 million pounds of ozone-depleting R-114 refrigerant. Releases from the refrigerant and cooling systems are tracked under 40 CFR Part 82 and the

PGDP's Title V (air) Permit. Approximately 2.2 million pounds of R-114 refrigerant is stored in railcars at the PGDP. The DOE was evaluating the disposition of its R-114 refrigerant during CY 2016.

Figure 2.3 Railcars utilized for the storage of R-114 refrigerant.

2.4 WATER QUALITY AND PROTECTION

2.4.1 Clean Water Act

The Clean Water Act (CWA) was established in 1972 through the Federal Water Pollution Control Act Amendments. The four major CWA programs are: 1) Regulation of point-source discharges into waters of the United States; 2) Control and preventions of oil and hazardous substances spills; 3) Regulation of dredge and fill materials discharges into waters of the United States; and 4) Financial assistance for construction of publicly owned sewage treatment works. PGDP surface water discharges are regulated through two (2) Kentucky Pollutant Discharge Elimination System (KPDES) permits.

2.4.2 Kentucky Pollutant Discharge Elimination System (KPDES)

The Kentucky Division of Water (KDOW) issues a Kentucky Pollutant Discharge Elimination System (KPDES) permit to the PGDP through its authority under the CWA. The permit applies to all non-radiological DOE discharges to Bayou Creek and Little Bayou Creek surface water, requires monitoring of discharge-related effects in the Creeks and adoption of Best Management Practices (BMPs) to minimize discharges. The PGDP complies with its KPDES permits through the application of Environmental Management System and work control BMPs.

No Notices of Violation were received during CY 2016 for KPDES permit exceedances. Table 2.2 summarizes 2016 KPDES permit exceedances (non-compliances) and measures taken to address them.

*Table 2.2. KPDES Noncompliance's in CY 2016**

Permit Type	Outfall	Parameter	Number of Permit Exceedances	Number of Samples Taken	Number of Compliant Samples	Percent Compliance	Month of Exceedance	Description/ Solution
KPDES*	020	Toxicity	2	8	6	75%	October and December	DOE has entered into a toxicity reduction evaluation. Notices of violation for these exceedances were not received in 2016.

*The permit type is KPDES (KY0004049).

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

The PGDP implements energy and water audits to comply with the Energy Independence and Security Act. Audits address building envelope, lighting, occupancy sensors, antiquated and leaking water system fixtures. Audit findings are immediately addressed, and previous audits are presented in the PGDP Site Sustainability Plan (SST 2016).

2.4.4 Safe Drinking Water Act

The PGDP utilizes the Ohio River as the source for on-site drinking water and treats the water prior to distribution. The drinking water treatment and distribution system was operated and managed by DOE contractors in accordance with the Safe Drinking Water Act (SDWA) regulations. FPDP maintains PGDP's water withdrawal permit for withdrawal of up to 30 mgd (million gallons per day). FPDP operates the sites non-transient non-community water system using lime softening, coagulation, sedimentation, filtering, and disinfection for treatment. The water system is operated under KDOW requirements for water systems serving populations of less than 10,000. In 2016 the PGDP sanitary water system monitoring results were compliant with State and Federal Maximum Contaminant Levels established under the SDWA. In March 2016 the site received an SDWA Notice of Violation for failure to submit copper and lead results for the January 2015 through December 2015 reporting period. The required remedial measure to address the Notice of Violation was the public notification of the violation and submission of the copper and lead results.

The SDWA establishes a framework for the Underground Injection Control program to control the injection of wastes into groundwater which includes injections associated with the implementation of remediation actions. In previous calendar years, the PGDP utilized subsurface electrical conductivity during the C-400 Cleaning Building Interim Remedial Action (Figure 2.1) to generate heat which in turn volatilizes trichloroethene (TCE) contamination in soil and aquifer materials. The remedial action required re-injection of treated groundwater to maintain electrical conductivity targets at subsurface electrodes. Activities at the PGDP during 2016 did not require compliance with the SDWA Underground Injection Control Program.

Figure 2.4 Remedial operations at the C-400 Cleaning Facility

2.5 OTHER ENVIRONMENTAL STATUTES

2.5.1 Endangered Species Act

The Endangered Species Act of 1973 addresses the designation and protection of endangered and threatened animals, plants, and their ecosystems. Endangered species that may be present in the vicinity of the PGDP are listed in Table 2.3. No DOE project at the Paducah Site during 2016 impacted any of the identified species or their potential habitats.

2.5.2 National Historic Preservation Act

The National Historic Preservation Act of 1966 requires federal agencies to identify and protect historic properties eligible to be placed on the National Register of Historic Places (NRHP). A PGDP Cultural Resources Survey (BJC 2006) and PGDP Cultural Resources Management Evaluation and Plan identified buildings of historical significance at the PGDP. The PGDP Historic District contains 101 site properties eligible for the NRHP including process buildings, electrical switchyards, the C-100 Administration Building, recirculating process water cooling towers and pump houses, security facilities; water treatment facilities, storage tanks, and support, maintenance, and warehouse buildings.

*Table 2.3. Federally Listed, Proposed, and Candidate 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 2017).

2.5.3 Migratory Bird Treaty Act

The U.S. Fish and Wildlife department and DOE updated a Memorandum of Understanding that requires further implementation of the Migratory Bird Treaty Act of 1918 under Executive Order 13186 (*Responsibilities of Federal Agencies to Protect Migratory Birds*). Under the Act, DOE must take measures to minimize impacts to migratory birds in the course of site and environmental operations. During CY 2016, the PGDP minimized impacts to migratory birds by avoiding disturbance of active nests.

2.5.4 Asbestos Program

Facilities at the PGDP contain asbestos material that requires compliance with programs addressing identification, monitoring, abatement, and disposal of asbestos materials. The PGDP maintains compliance with EPA, Occupational Safety and Health Administration, and Kentucky regulatory requirements regarding asbestos. During PGDP historical decontamination and decommissioning (D&D) of the C-340 Metals Plant, insulation containing asbestos was abated.

2.5.5 Floodplain/Wetlands Environmental Review Requirements

The Code of Federal Regulations, 10 CFR 1022, and Executive Orders 11988 (*Floodplain Management*) and 11990 (*Protection of Wetlands*) require compliance to protect Floodplains and Wetlands. DOE activities did not result in significant impacts to floodplains or wetlands in 2016.

2.5.6 Underground Storage Tanks Managed under RCRA Kentucky UST Regulations

Eighteen (18) PGDP Underground Storage Tanks (USTs) were used during plant construction and operations to store petroleum products. The UST's are regulated under RCRA Subtitle I (40 *CFR* § 280) and Kentucky UST regulations (401 *KAR* Chapter 42) administered by the Kentucky Division of Waste Management (KDWM). Fourteen (14) USTs have been closed under regulatory closure plans, two USTs were determined not to exist, and the remaining two (2) USTs were inactive and undergoing closure in CY 2015. No Underground storage tanks were in service at the PGDP during CY 2016.

USTs at the PGDP are monitored by the PGDP and the Kentucky Division of Waste Management. Of the 18 underground storage tanks once in service at the PGDP, only 2 were still in operation during 2014.

2.5.7 Solid Waste Management

The Paducah Site disposes of a portion of the solid waste generated at the PGDP in the site's contained landfill facility, the C-746-U Solid Waste Contained Landfill. The landfill operated under Solid Waste Permit SW07300045 administered by the KDWM and requires quarterly submission of operating and groundwater monitoring reports. During 2016, office waste generated at the PGDP was taken off-site for disposal by a commercial waste-disposal company. The City of Kevil picks up the office waste from site administrative support offices in Kevil, Kentucky.

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

2.6.1 Department Sustainability

The PGDP, through DOE Order 436.1, pursues the U.S. Green Building Council's Leadership in Energy and Environmental Design guidelines. The PGDP currently has no buildings or proposed construction that fall under this order.

2.6.2 Federal Leadership in Environmental, Energy and Economic Performance

In support of DOE's goals to reduce greenhouse gas emissions, PGDP contractor Swift and Staley submitted a Site Sustainability Plan in December 2016 and FPDP submitted a Site Sustainability Plan in December 2014.

2.7 Emergency Planning and Community Right-to-Know Act

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 of hazardous chemicals to the environment, including greenhouse gases. The purpose of EPCRA is to increase the public's knowledge and access to information about chemical hazards in their communities.

The Paducah Site, as a federal facility, is subject to EPCRA reporting requirements. EPCRA Section 304 requires facilities to notify state and local emergency response and planning entities about releases of hazardous and extremely hazardous substances that equal or exceed reportable quantities. EPCRA Sections 311 and 312 require facilities to report locations and quantities of chemicals to state and local emergency response entities to facilitate emergency response actions. EPCRA Section 313 requires EPA and states to collect and publish annual data on releases and transfers of specified toxic chemicals at industrial facilities.

The DOE and PGDP contractors submitted no notifications Section 311 notifications for new chemicals at the site in 2016. BWCS submitted a Section 313 report for the production of hydrofluoric acid at the DUF6 conversion facility in 2016. The DOE submitted a Section 313 report for chlorine utilized in water sanitation. A number of chemicals stored at the site by contractors were included in a Section 312 Report. Table 2.4 summarizes the CY 2016 EPCRA reporting status for the PGDP.

Table 2.4. 2016 PGDP EPRCRA Report Status

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 implements cost-effective sustainable methods to reduce environmental and social impacts of remedial cleanup and closure activities.

2.8.2 Adapting to Climate Change

Through 2016, the PGDP has not partnered with federal or local agencies to implement or explore implementation of measures to mitigate climate change.

2.9 Continuous Release Reporting

CERCLA Section 103(a) requires reporting of hazardous substance releases that exceed continuous and stable releases to the National Response Center. PGDP reports those releases in Superfund Amendments and Reauthorization Act Title III reports and notifications. In 2016, PGDP had no reportable continuous releases at the PGDP.

2.10 Unplanned Releases

In August 2016 storm water discharge containing paint was reported at KPDES Outfall 011. Other unplanned environmental releases at the Paducah Site during CY 2016 were below reportable quantities.

2.11 Summary of Permits

The DOE's required PGDP environmental permits for CY 2016 are listed in Table 2.5.

Table 2.5 CY 2016 Environmental Permits Maintained by DOE for the Paducah Site

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/FFS/BWCS*
		KY0102083	DOE/FFS
Permit to Withdraw Public Water	KDOW	0900	FFS
Water Treatment Registration	KDOW	Public Water System KY0732457	FFS
Clean Air Act			

Conditional Major Operating Air Permit	KDAQ	F-10-035 R1/F-15-042	BWCS*
Title V Air Permit	KDAQ	V-14-012 R1	FFS
RCRA—Solid Waste			
Residential Landfill (closed)	KDWM	SW07300014	DOE/FFS
Inert Landfill (closed)	KDWM	SW07300015	DOE/FFS
Solid Waste Contained Landfill (construction/operation)	KDWM	SW07300045	DOE/FFS
RCRA—Hazardous Waste			
Hazardous Waste Facility Permit	KDWM	KY8-890-008-982	DOE/FFS
Underground Storage Tank Registration	KDWM	6319-073	DOE
Hazardous and Solid Waste Amendments Portion of the RCRA Permit	EPA	KY8-890-008-982	DOE/FFS

*BWCS was replaced by Mid-America Conversion Services, LLC, in February 2017.

3.0 Environmental Management System

The Environmental Management System (EMS) is a management approach that the PGDP site uses to integrate its environmental protection, environmental compliance, pollution prevention, health and safety work. The EMS implements sound practices for the protection of land, air, water, natural and cultural resources potentially impacted by site operations and addresses all work conducted by the DOE and its prime contractors. The five major elements of the PGDP EMS are policy, planning, implementation and operation, and checking and management review as outlined by the International Organization for Standardization.

Each PGDP prime contractor is responsible for developing and implementing an EMS for its site activities. The PGDP receives an annual environmental scorecard ranking for its EMS activities. In FY 2016 the PGDP environmental stewardship scorecard for FY 2016 was green which indicates that the site effectively implemented its environmental stewardship activities.

3.1 Environmental Operating Experience and Performance Measurement

The DOE and site contractors conduct an environmental monitoring program for the PGDP which is described in the Environmental Monitoring Plan (EMP). The EMP identifies how effluent monitoring, environmental surveillance, and air monitoring around the plant will be conducted during the year. Site contractor FPDP implemented the PGDP 2016 EMP and executed EMP activities.

3.1.1 Site Sustainability Plan

The PGDP Site Sustainability Plan (SSP) is required by DOE Order 436.1 and Executive Order 13693. The SSP provides information concerning the requirements and responsibilities of managing sustainability at the Paducah Site. The SSP ensures DOE carries out its missions in a sustainable manner and addresses: 1) National energy security and global environmental challenges and advances sustainable, reliable and efficient energy for the future; 2) Initiation of wholesale cultural change to factor sustainability and GHG reductions into all of DOE's corporate management decisions; and 3) Implements measures to ensure that DOE achieves the sustainability goals established in its SSP pursuant to any applicable laws, regulations, Executive Orders (EO's), sustainability initiatives, and related performance scorecards.

The SSP is also intended to increase awareness in workers and the community about sustainability opportunities through public outreach and training. Table 3.1 is taken from the *Fiscal Year 2017 Site Sustainability Plan, Paducah Gaseous Diffusion Plant* and contains a brief summary of FY 2016 performance and long-term planned actions to attain FY 2020 SSP goals.

3.1.2 Waste Minimization/Pollution Prevention

The PGDP Waste Minimization/Pollution Prevention Program provides guidance and objectives for minimizing waste generated at the site. The program complies with RCRA requirements, the Pollution Prevention Act, Commonwealth of Kentucky and U.S. Environmental Protection Agency rules, DOE orders, EO's, and the Site Treatment Plan. PGDP site wastes are minimized using source reduction, segregation, reuse of materials, recycling, and procurement of recycled-content products.

The PGDP's SSP 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.

Table 3.1 DOE Goal Summary Table

DOE Goal	Site Performance
Greenhouse Gas Reduction	
Reduce greenhouse gas emissions by FY 2025 from an FY 2008 baseline.	Overall consumption has increased since the 2008 baseline due to USEC-leased facilities returning to DOE control, making achievement of the goal very challenging. Beginning in May 2016, site employees began working alternate work schedules, which aided in reducing emissions from employee vehicles.
Sustainable Buildings	
Reduce energy intensity.	Energy initiatives are challenging due to the age of the facilities.
Metering of all individual buildings for electricity, natural gas, steam, and water, where cost-effective and appropriate.	There are no plans to add meters for these utilities on-site because the site is in the deactivation phase. The C-103 DOE Site Office Building and some newer trailers are individually metered. Sustainable projects have been explored at the site. Facilities have been evaluated, and the C-103 DOE Site Office Building was considered for a cool roof project; however, a photovoltaic roof is not a cost-effective option for this facility at this time. Other buildings have not met DOE's cost-benefit analysis guidelines.
Increase regional and local planning coordination and involvement.	The site currently is involved in deactivation. As projects arise, there will be more opportunity for involvement.
Clean and Renewable Energy	
Work toward a percentage of total electric and thermal energy accounted for by renewable and alternative energy.	Presently, the site has no on-site renewable energy generation capability.
Work toward a percentage of total agency electric consumption being renewable electric energy.	DOE purchased renewable energy certificates for the Paducah Site and plans to continue purchasing certificates necessary to support meeting the site's goal.
Water Use Efficiency and Management	
Reduce potable water intensity. Reduce water consumption of industrial, landscaping, and agricultural.	Site numbers indicate that the goals have not been achieved due to the consolidation of all plant facilities under DOE. Total potable water flow data reported to KDOW showed a reduction in the past FY.
Fleet Management	
Reduce annual petroleum consumption.	Plant personnel are encouraged to use alternative fuel vehicles, and the contractors are promoting E-85 use.
Increase annual alternative fuel consumption.	The fleet is primarily E-85 vehicles, with a number of hybrids, which are encouraged to be utilized during travel.

DOE Goal	Site Performance
Reduce fleet-wide, per-mile greenhouse gas emissions.	Sitewide fleet totals have increased with the addition of the Deactivation contractor and its fleet vehicles.
Purchase alternative fuel vehicles for light-duty vehicles.	The majority of the site's fleet consists of alternative fuel vehicles.
Acquire passenger vehicles that consist of zero emission or plug-in hybrid electric vehicles.	No vehicles on-site meet criteria, at this time. With guidance from Executive Order 13693, DOE sites are moving toward more alternative fuel consuming vehicles, such as zero-emission vehicles and plug-in hybrids to further sustainability goals. The Paducah Site has not had a need to directly purchase vehicles for several years.
Sustainable Acquisition	
Promote sustainable acquisition and procurement to the maximum extent practicable ensuring bio-preferred and bio-based provisions and clauses in applicable contracts.	Applicable contracts contain sustainable acquisition clauses.
Pollution Prevention and Waste Reduction	
Divert from landfills nonhazardous solid waste, excluding construction and demolition debris through recycling and waste minimization.	The site exceeds it goals in diverting eligible waste.
Divert from landfills construction and demolition materials and debris through recycling and waste minimization.	The site exceeds it goals in diverting eligible construction and demolition materials and debris.
Energy Performance Contracts	
Implement performance contracting as part of the planning of Section 14 of Executive Order 13693.	No energy savings performance contracts are in place currently at the site; however, potential projects are being considered that may provide an opportunity where energy savings performance contracts could be used.
Electronic Stewardship	
Purchase Electronic Product Environmental Assessment Tool-registered products.	Most electronic acquisitions currently meet standards.
Enable eligible personal computers, laptops, and monitors with power management.	Power management is implemented actively on computers.
Enable eligible computers and imaging equipment with automatic duplexing.	Eligible computers and printers have duplexing capabilities.
Reuse or recycle used electronics using environmentally sound disposition options each year.	In FY 2016, there were no electronic scrap shipments. Arrangements with an off-site vendor currently are being negotiated for a large shipment of electronic scrap.

DOE Goal	Site Performance
Climate Change Resilience	
Update policies to incentivize planning for and addressing the impacts of climate change. Update emergency response procedures and protocols to account for projected climate change, including extreme weather events. Ensure workforce protocols and policies reflect projected human health and safety impacts of climate change. Ensure site/laboratory management demonstrates commitment to adaptation efforts through internal communication and policies. Ensure that site/laboratory climate adaptation and resilience policies and programs reflect best available current climate change science, updated as necessary.	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.

The accomplishments of the PGDP Waste Minimization/Pollution Prevention Program in CY 2016 (DOE 2017a) were: 1) Regenerated 29,340 pounds of activated carbon averting disposal; 2) Recycled 272,680 pounds of scrap metal from demolition of small buildings; 3) Recycled 10,901 pounds of various light bulbs; 4) Recycled 69,734 pounds of various batteries; and 5) Shipped 9,226 pounds of miscellaneous liquids from radiological areas to be burned for energy recovery. The PGDP Waste Minimization/Pollution Prevention Program efforts for the site are reported in DOE's Consolidated Energy Data Report.

3.1.3 Depleted Uranium Hexafluoride Cylinder Program

The safe storage, re-use, recycling and disposition of DUF6 continues to be a significant part of PGDP's operations. Safe storage of the DOE-owned DUF6 cylinders is managed through the DOE's DUF6 Cylinder Program. The re-use, recycling and ultimate disposition of DUF6 is managed through the DUF6 Conversion Program.

Depleted uranium hexafluoride (DUF_6) is a product of the uranium enrichment process and had economic value as re-processed feed material when the enrichment process was operating. About 1 billion pounds of DUF_6 are stored at the Paducah Diffusion Plant in 12 foot by 4 foot metal cylinders. During operations low-enriched uranium (LEU) was shipped to other facilities for further processing and the remaining uranium was stored as DUF_6 in outdoor cylinder yards covering more than 100 acres (76 football fields) of the site. There were more than 52,000 DUF_6 cylinders stored at the PGDP in 2016 which continues to represent the largest stockpile of mined uranium in the world.

Conversion of DUF6 for disposition is conducted at the PGDP DUF6 Conversion Facility. The Conversion Facility converts DUF_6 to a more stable uranium oxide and hydrofluoric acid which is sold for industrial re-use. In 2016 facility operator BWCS converted 235 metric tons of DUF6 before the transfer of facility operations to Mid-America Conversion Services, LLC.

3.1.4 Environmental Restoration, Waste Disposition, and Decontamination & Decommissioning

The environmental restoration program encompasses: 1) Investigations and environmental response actions; 2) D&D of facilities no longer in use; 3) Projects designed to demonstrate or test advancements in remedial technologies; and 4) Other projects related to actions taken for the protection of human health and the environment.

Environmental Restoration, Waste Disposition and D&D accomplishments during 2016 include:

- Removed contents of an acid neutralization tank and abandoned it in place (SWMU 27).
- Fieldwork start to support the optimization of the Northeast Plume containment system.

- Submission of a Remedial Investigation Report for a historical burial ground (SWMU 4).
- Submission of a Remedial Investigation Report for soil area beneath a former material storage area (SWMU 229)
- Submission of a revised Burial Grounds Operable Unit SWMUs 5 and 6 Proposed Plan.
- Submission of and regulatory approval for C-400 Phase IIb Revised Treatability Study Report.
- Submission of and regulatory approval for Soils Operable Unit Remedial Investigation 2 Report.

3.1.5 Emergency Management

Emergency Management is an integrated systematic effort at the PGDP. The PGDP Emergency Response Organization includes the Emergency Operations Center cadre, the crisis manager, an incident commander, and the Emergency Squad. The PGDP Joint Public Information Center provides timely and accurate information to the community during emergency situations. The PGDP maintains a fully staffed fire department, protective security force and staffed medical facility. Emergency response procedures are regularly practiced during training exercises.

3.1.6 Facility Stabilization, Deactivation, and Infrastructure Optimization

The PGDP enrichment facilities are regulated under DOE Orders. During 2016 several enrichment facility optimization modifications were completed:

- Sampling and repackaging of the trap mix containers in one of the process buildings were completed to support waste characterization for future demolition.
- Disposed of loose material and spare parts (predominantly process gas equipment) that were not being used at the C-720 Maintenance and Stores Building and the C-400 Cleaning Building any longer.
- DOE transferred ownership of the Site coal stockpile to the Paducah Area Community Re-use Organization to provide revenue supporting economic development
- Overhead utility lines from the TVA Shawnee Steam Plant to the PGDP were abandoned and reconfigured to meet current Site electrical demand.

Figure 3.1 Transfer of the PGDP coal inventory to PACRO

3.1.7 Accomplishments, Awards, and Recognition

The DOE and Site contractors were committed to enhancing public awareness of PGDP activities through community and educational outreach programs.

3.1.8 Public Awareness Program

A comprehensive DOE Community Relations and Public Participation Program (DOE 2016b) was updated in CY 2016. The Program provides the public with opportunities to become involved in decisions relating to environmental issues at the PGDP site.

During CY 2016 DOE's PGDP EM Program conducted inaugurated and conducted eight guided public tours of the PGDP site (Figure 3.2).

Figure 3.2 Participants in the inaugural PGDP Site Tour visit the C-300 Central Control Facility

3.1.9 Community/Educational Outreach

The DOE supported several educational and community outreach activities during 2016. Site employees participated in a "Feds Feed Families" program to donate non-perishable food items to area food banks (Figure 3.3). Education outreach programs included the PGDP Marshall County High School Student ASER Program, the Western Kentucky Regional Science Bowl for area middle and high schools, the Western Kentucky Regional Science Fair, local school career fairs and a local elementary and middle school groundwater mentoring program (Figure 3.4).

Figure 3.3. Feds feed Families Donations Display.

Figure 3.4 DOE contractor personnel demonstrate mechanisms for environmental impacts on groundwater to area elementary and middle school students.

In a joint project between DOE and the Kentucky Research Consortium for Energy and Environment (KRCEE), students from Marshall County High School participated in program that produced a summarized version of a previous year's PGDP Annual Site Environmental Report, received briefings from subject matter experts about PGDP history & operations, nuclear science, environmental impacts, and ecology and also participated in field ecological data collection activities in the vicinity of the PGDP (APPENDIX B – MCHS STUDENT ASER 2018-19 Activities). Additional information is available at http://www.ukrcee.org/edu.html (Figure 3.5). The KRCEE continued development of a PGDP Virtual Museum during 2016 to document the history and accomplishments of the PGDP as an interactive web resource.

Figure 3.5. Marshall County High School ASER Program CY 2016 site tour.

In 2016, 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.

Paducah PPPO Environmental Geographic Analytical Spatial Information System (PEGASIS), was updated in 2016. 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. Training sessions for PEGASIS are available by contacting the PEGASIS administrator. See http://pegasis.ffspaducah.com/what-is-pegasis.html.

3.1.10 Citizens Advisory Board

The Paducah Citizens Advisory Board (CAB) is a site-specific advisory board chartered by DOE under the Federal Advisory Committees Act. The CAB is composed of up to 18 members chosen to reflect the diversity of the PGDP area. The CAB reflects the community concerns regarding the environmental management of the PGDP site and conveys those concerns to the DOE. The CAB meets bimonthly to focus on early citizen participation in environmental cleanup priorities and related issues at the DOE facility.

The PGDP CAB completed its 20th year of operation in 2016. During the year, the CAB held regular board meetings and additional subcommittee meetings. During 2016 the PGDP CAB subcommittees addressed issues related to the following PGDP subjects:

- Decontamination and Decommissioning
- Environmental Restoration
- Community Engagement
- Integrated Priority List

PGDP CAB meetings were open to the public and all regular board meetings were publicly advertised. In addition to its voting members, the CAB also has liaison members representing EPA Region 4, KDWM, Kentucky Cabinet for Health and Family Services, and WKWMA.

3.1.11 Environmental Information Center

DOE's activities at the PGDP generate numerous technical, project and regulatory documents. The DOE Environmental Information Center provides the public centralized access to electronic documents that are part of the Administrative Record (www.paducaheic.com). 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. 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.

The Environmental Information Center and other public web pages related to DOE work at the Paducah Site can be accessed at www.paducaheic.com and http://energy.gov/pppo/paducah-site.

4.0 Environmental Radiological Protection Program and Dose Assessment

Background information about radioactive material that supports radioactive materials and radiation discussions in this section of the ASER is presented in Appendix C – Radiation and Radioactive materials Primer and on the KRCEE website http://www.krcee.org under the ASER tab 'Nuclear Energy and the Atom'.

4.1 Environmental Radiological Monitoring Program

Routine operations at the PGDP have the potential to release radioactive materials into the environment by atmospheric and liquid pathways. The releases have the potential to result in a radiation exposure to the public and the environment. DOE Order 458.1, *Radiation Protection of the Public and the Environment,* requires an environmental surveillance program be in place at DOE sites and that the surveillance programs include radiation monitoring of the pathways which could result in an exposure to the public. At the PGDP, environmental radiation surveillance includes the following pathways: surface water, groundwater, sediment, direct radiation, and ambient air.

4.1.1 Dose

Exposure to radiation results in a transfer of energy from radiation to an individual. The transfer of energy can result in tissue damage. Exposures may be external from radionuclides outside the body or internal from radionuclides inside the body. Dose is the amount of energy absorbed by the human body as a result of exposure to a source of radiation. Dose is measured in rems or millirems (mrem). DOE Order 458.1 establishes an acceptable dose limit for the public of 100 mrem per year. The PGDP monitors the presence and releases of radiation as well as the amount of radiation that the general public receives. The PGDP utilizes the radiation monitoring data to confirm that doses from site operations are below the public and individual dose limits established in DOE Order 458.1.

The public is routinely exposed to natural and man-made sources of radiation (Figure 4.1). DOE has established dose limits to the public so that DOE operations will not contribute significantly to the average annual exposure. Each year, PGDP operations may contribute to the public or individuals' dose through releases of and resulting exposure to radioactive material. The PGDP monitors releases of its radioactive materials and calculates an annual dose amount through:

- The use of effluent release data
- Direct radiation monitoring data
- Environmental monitoring data (along with relevant site-specific data)

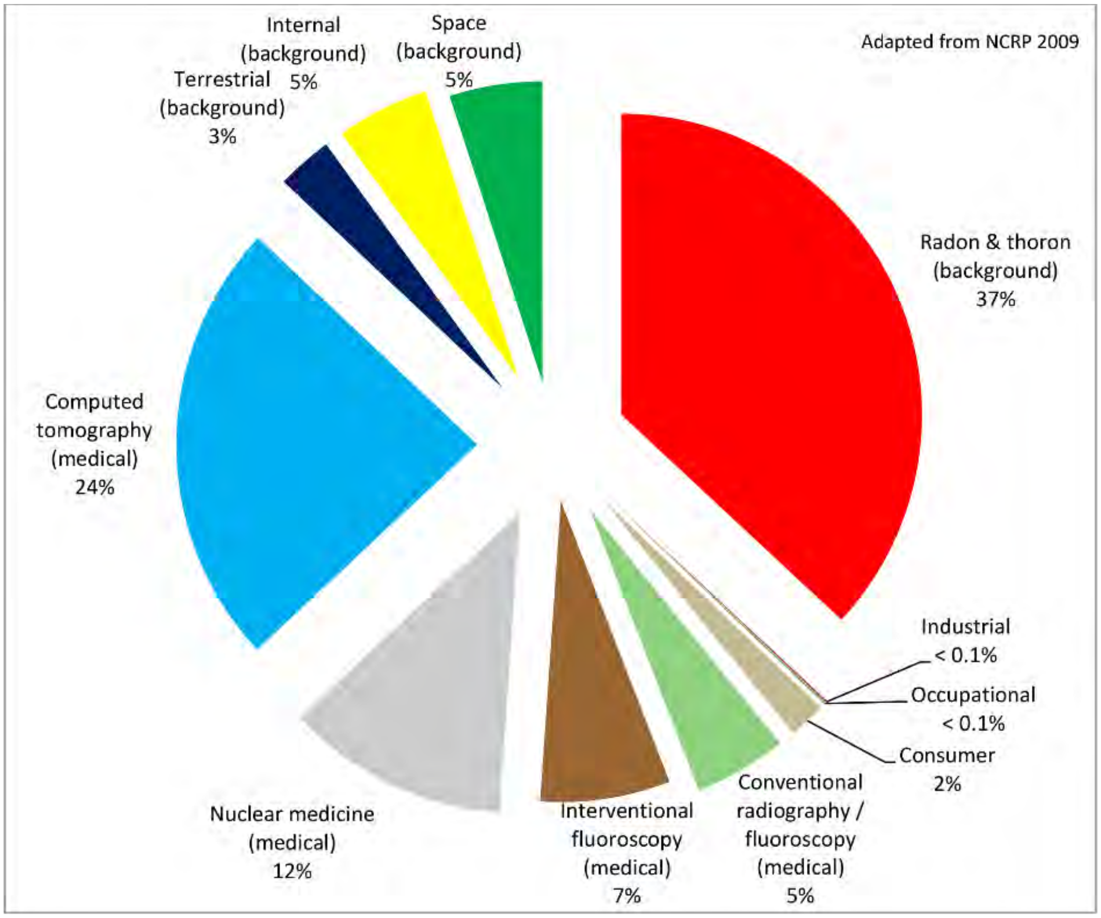


Figure 4.1 The percentage of dose received by individuals from all sources of ionizing radiation.

4.1.2 Radioactive Materials at the Paducah Site

Radioactive materials at the PGDP are the result of processing raw and recycled uranium into nuclear materials. Uranium is a common element in the environment that occurs at concentrations greater than the well-known elements silver and gold. Technetium is a man-made element that is a product of the fission process in nuclear reactors and was introduced at the PGDP during the recycling/reprocessing of spent nuclear fuel.

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)
Neptunium-237 (2,140,000 year half-life)
Americium-241 (432 year half-life)
Cesium-137 (30.2 year half-life)

4.1.3 What is an Exposure Pathway?

An exposure pathway is the route for released radioactive material to be transported by an environmental medium from a source to a receptor (a receptor is a plant, person, or animal). Routine operations at the PGDP and DUF6 facilities release incidental radioactive materials into the environment through atmospheric and liquid discharges.

The principal routes by which people potentially are exposed are summarized by the following bullets and Figure 4.2:

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

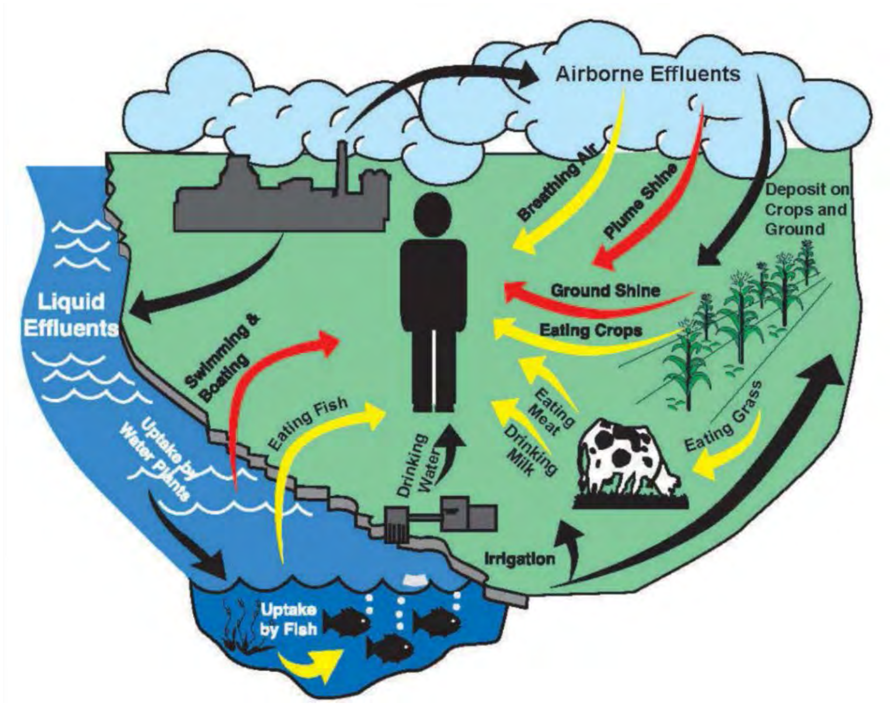


Figure 4.2 Radioactive material exposure pathways.

4.1.4 Dose Assessment Methodology

Dose assessment at the PGDP is conducted utilizing methods consistent with DOE Order 458.1, other guidance documents and *Methods for Conducting Risk Assessments and Risk Evaluations* (DOE 2016a). Measurements of radionuclide concentrations in liquids and air released from the PGDP are modeled to estimate the maximum exposure to an individual in a year. The population living within a 50-mile radius of Paducah Site is evaluated in the Site's assessment of compliance with public off-site dose limits. In the assessment, the maximally exposed individual (MEI) is the hypothetical resident who has the greatest probability of being affected by a radiological release. The MEI is exposed to air releases at the highest concentration of radionuclides that were measured in air during a year. The MEI consumes milk, meat, and vegetables produced at that location; spends time on or near Bayou or Little Bayou Creek, hunts on the wildlife reservation and consumes hunted wildlife. Groundwater consumption is not considered for the MEI because all persons downgradient of the Paducah Site are provided water from the local public water supply system.

Dose from ingestion of surface water is calculated at the nearest public withdrawal location in Cairo Illinois. Dose from sediment ingestion and incidental contact with surface water 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 MEI located at the nearest plant neighbor.

Additional assumptions related to the Paducah Site MEI are that surface water is not used for irrigation of crops. Little Bayou Creek is an ephemeral stream and does not support aquatic life for consumption. Fish are not caught and consumed from Bayou Creek, so fish ingestion is not considered.

4.1.5 Air Monitoring and Estimated Dose from Airborne Effluents

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, National Emission Standards for Hazardous Air Pollutants, 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 per year to any member of the public.

DOE operations that may result in airborne radionuclide releases included CERCLA remedial actions and fugitive emissions. Several potential radionuclide sources were evaluated at the PGDP in 2016 including groundwater treatment facilities and the DUF6 Conversion facilities, including:

- Northwest Plume Groundwater Pump and Treat System
- Northeast Plume Groundwater Alternate Pump and Treat System
- DUF6 Conversion Facility
- C-709/C-710 Laboratory Hoods
- Seal and wet air exhaust systems in PGDP process and process support buildings

Specific activities that could generate fugitive emissions include transport and disposal of waste, decontamination of contaminated equipment and environmental remediation activities. Ambient air monitoring of fugitive emissions from all Paducah Site operations is conducted using eight continuous air monitors surrounding the Paducah Site and portions of the Paducah DOE reservation and one background air monitor (Figure 4.3). Radioactive analytes are identified in the FY 2016 and FY 2017 Environmental Monitoring Plans (FPDP 2016; FPDP 2017a).

CY 2016 radioactive materials releases from stacks and diffuse PGDP sources were modeled using the EPA approved computer code CAP-88. The CAP-88 air dispersion models utilize PGDP meteorological data and calculates dose based on ingestion, inhalation, air immersion and ground pathways. Table 4.1 provides site estimates of atmospheric releases in curies and Table 4.2 provides the modeled dose to the MEI from individual PGDP point sources.

*Table 4.1 Radionuclide Atmospheric Releases for CY 2016 (in Curies) for the Paducah Site**

Radionuclide	Northwest Plume Groundwater Treatment System	Northeast Plume Containment System Alternate Treatment Unit	DUF_6 Conversion Facility	C-709 & C-710	Seal Exhaust/ Wet Air Group	Total Site Emissions
U-234	0	0	5.46E-07	1.54E-04	9.19E-07	1.55E-04
U-235	0	0	2.50E-08	5.35E-06	3.19E-08	5.41E-06
U-238	0	0	1.34E-06	1.43E-05	2.44E-05	4.00E-05
Tc-99	9.59E-05	6.37E-06	0	0	1.08E-06	1.03E-04
Th-230	0	0	0	0	4.42E-09	4.42E-09
Th-231	0	0	6.84E-08	0	0	6.84E-08
Th-234	0	0	6.24E-06	0	0	6.24E-06
Pa-234m	0	0	6.24E-06	0	0	6.24E-06
Total Curies/Year	**9.59E-05**	**6.37E-06**	**1.45E-05**	**1.74E-04**	**2.64E-05**	**3.17E-04**

*Values are taken from *National Emissions Standard for Hazardous Air Pollutants Annual Report for 2016* (FPDP 2017c)

Table 4.2 Dose Calculations for Modeled CY 2016 Airborne Releases from Point Sources

Emission Sources	Dose to the Maximally Exposed Individual for the Plant (mrem)
Northwest Plume Groundwater Treatment System	6.7E-05
Northeast Plume Containment System Alternate Treatment Unit	1.2E-06
DUF_6 Conversion Facility	5.5E-07
C-709 & C-710	4.9E-05
Seal Exhaust/Wet Air Group	1.3E-05
Total from All Sources	1.3E-04

The hypothetical maximally exposed individual was calculated potentially to receive an effective dose equivalent of 0.00013 mrem, which is well below the National Emission Standards for Hazardous Air Pollutants standard of 10 mrem. The calculated CAP-88 collective effective dose for the entire population within 50 miles of the PGDP is in Table 4.3.

Table 4.3 Calculated Radiation Doses from PGDP Airborne Releases for CY 2016.

Effective Dose to Maximally Exposed Individual (mrem)	Percent of Standard (%)	Collective Effective Dose (person-rem)
1.3E-04	0.0013	9.1E-04

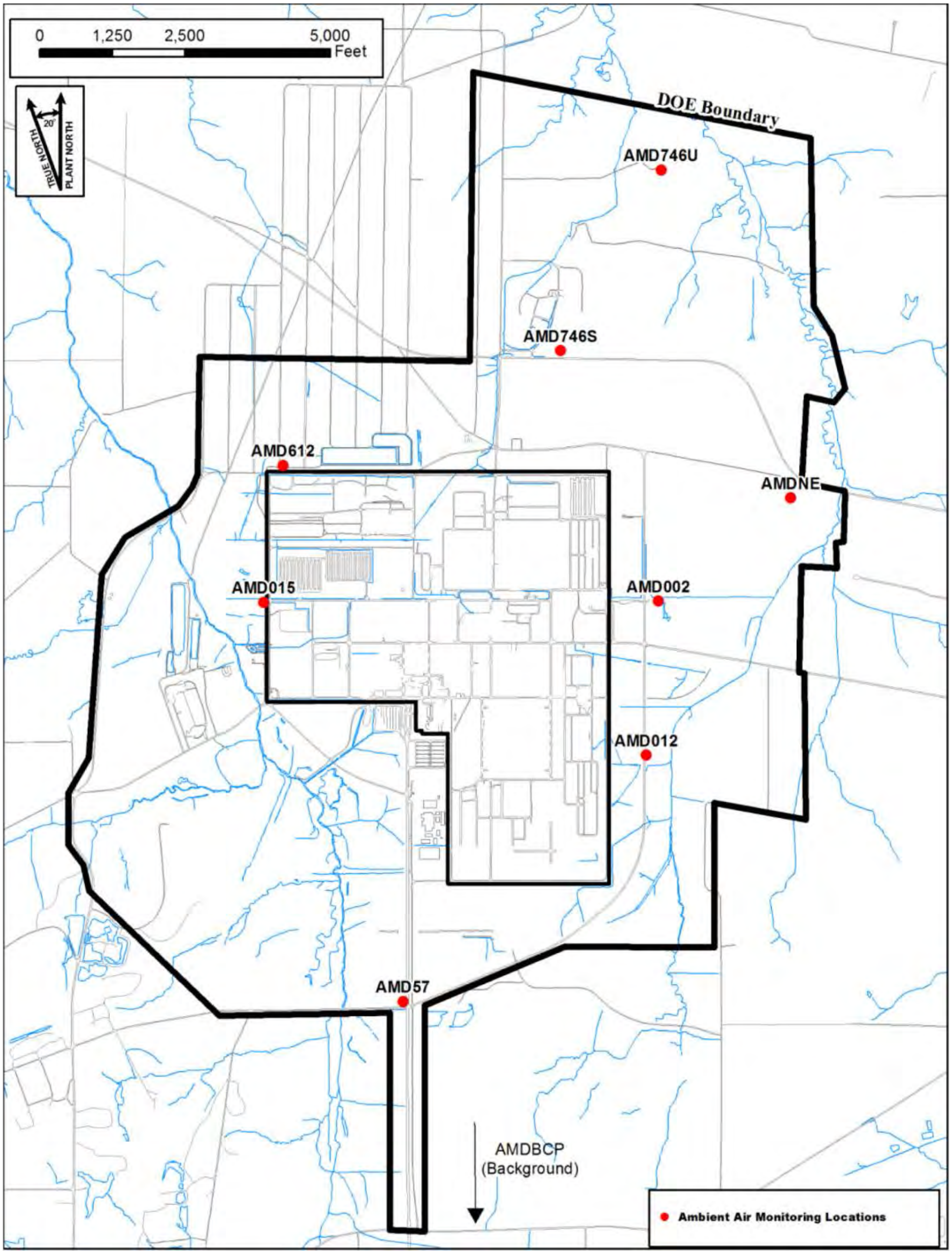


Figure 4.3 Air Monitoring Locations.

4.1.6 Liquid Discharge Monitoring and Estimated Dose from Liquid Effluents

4.1.6.1 Surface Water

DOE Order 458.1 sets the requirements for limiting radioactivity in liquid releases from the PGDP so that they are protective of human health. The Derived Concentration Technical Standard is a calculation for each radioisotope in a media which converts the concentration to a dose and the doses are summed to determine the dose to the MEI.

Radioactive materials released to surface water may remain dissolved or suspended in surface water. Those materials may be deposited in sediment, deposited on ground or vegetation by irrigation, absorbed by plants and animals or they may infiltrate to groundwater. Surface water leaving the Paducah Site includes runoff from rainfall, runoff from cylinder yards and landfills, and discharged effluent from site processes. Paducah Site surface water flows through site ditches and into Bayou and Little Bayou Creeks. Bayou and Little Bayou Creeks discharge into the Ohio River.

During 2016, surface water environmental surveillance monitoring was conducted quarterly at four locations (Figure 4.4), one background location, and a downstream Ohio River location near the Cairo, Illinois public water supply withdrawal location. Locations were prioritized for areas of public access, introduction of plant effluents to the environment and verification of the effectiveness of the effluent discharge controls.

Isotopic analysis for multiple radionuclides is performed for samples collected at environmental, quarterly and permitted sampling locations. If a sample contains alpha and beta activity at levels below established screening thresholds, no further analyses are conducted for radioisotopes. The screening threshold is 14 pCi/L for alpha activity and 300 pCi/L for beta activity. During 2016 no surface water environmental surveillance monitoring location samples exceeded the alpha or beta screening thresholds.

In addition to the environmental surveillance monitoring locations, samples were taken throughout the year near twenty (20) KPDES-permitted outfalls. Threshold values were exceeded during CY 2016 at KPDES Outfalls O11, 015 and 020.

Effluent surface water sampling is conducted at five (5) locations associated with the C-746-S&T and C-746-U Landfills and one location associated with Northeast Plume effluent.

CY 2016 isotopic analyses of surface water surveillance and KPDES outfalls samples is summarized in Table 4.4.

Table 4.4. Ranges of radionuclides in 2016 Surface Water Samples

Isotope	Range
Technetium-99 (pCi/L)	2.01E+01–7.31E+01
Uranium-234 (pCi/L)	2.49E+00–3.34E+01
Uranium-235 (pCi/L)	1.20E-01–3.57E+00
Uranium-238 (pCi/L)	3.72E+00–1.43E+02

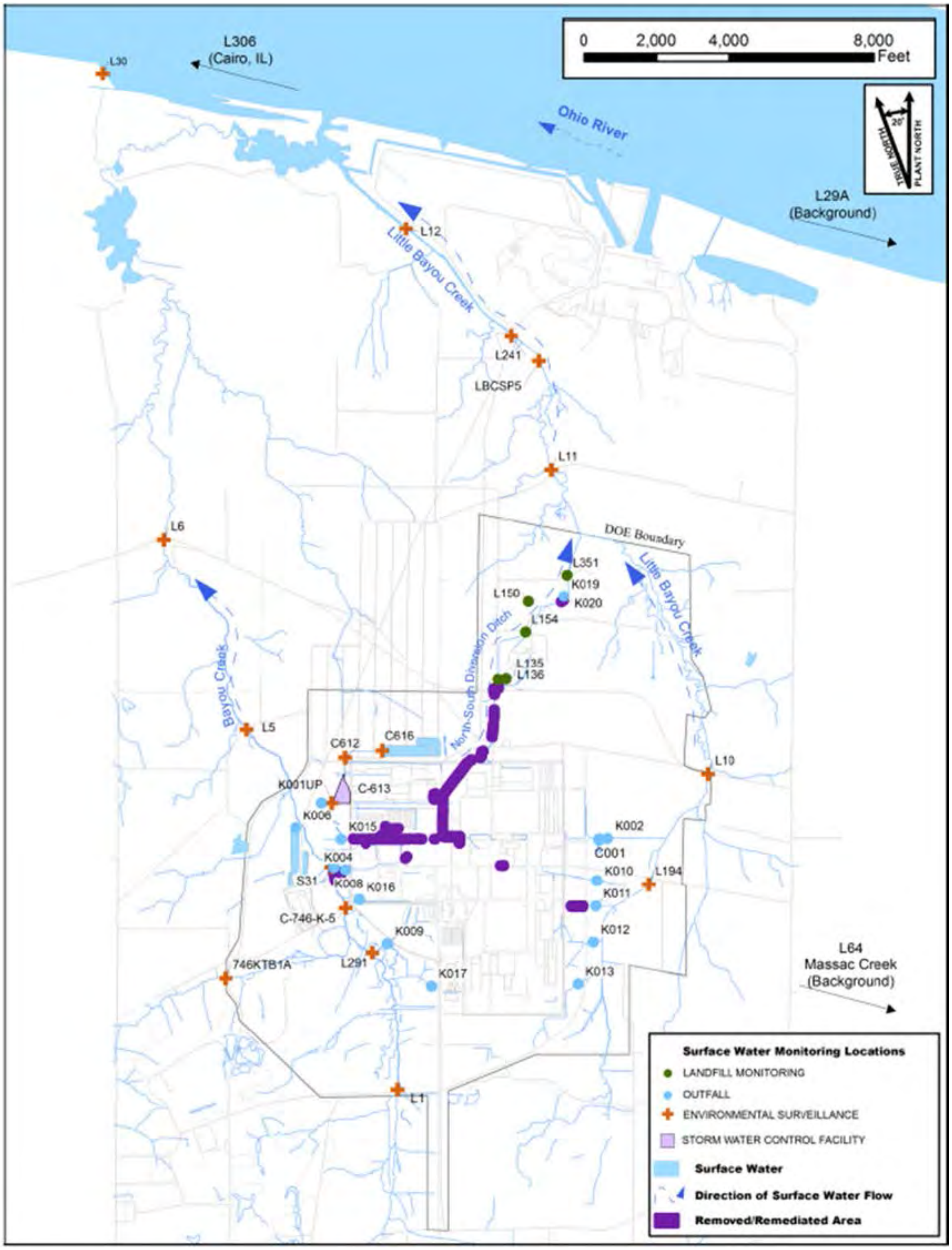


Figure 4.4 PGDP 2014 Surface Water Monitoring Locations.

4.1.6.2 Drinking Water

Surface water from the Paducah Site is not used as a drinking water source, but it is eventually discharged into the Ohio River, which is used as a public drinking water source at Cairo, Illinois, located downstream of Bayou Creek at the confluence of the Ohio and Mississippi Rivers. The concentrations of radionuclides detected near the surface water collection inlet at Cairo during CY 2016 were used to calculate the dose to the MEI resulting from consumption of surface water. The maximum alpha and beta activities detected in Cairo samples was 1.34 and

6.01 pCi/L, respectively. Maximum contaminant level (MCL) for alpha and beta activities are 15 pCi/L and 4 mrem/year, respectively.

The drinking water pathway dose was calculated for the MEI consuming water from the Cairo drinking water location. The maximum annual MEI dose was calculated to be 0.09 mrem/yr in 2016 as a default value since the Cairo location samples did not exceed alpha and beta screening thresholds and no isotopic analyses were conducted on the samples.

4.1.6.3 Incidental Ingestion of Surface Water

Dose to the hypothetical MEI is calculated based on incidental ingestion of surface water due to wading or swimming in Bayou and Little Bayou Creeks and their tributaries. The assumptions in the incidental ingestion of surface water dose assessment are that a recreator may swim or wade 45 days/year, 2.6 hours/day, and incidentally ingest 0.05 liters per hour while swimming. The highest monthly surface water results from the various sampling locations are utilized to calculate the upper level bounding concentration and resulting dose. The annual dose due to the incidental ingestion of surface water is 0.19 mrem/year.

4.1.6.4 Landfill Leachate

C-746-U Landfill leachate is sampled routinely and screened against DOE Order 458.1 limits. Results of CY 2016 C-746-U leachate sampling are included in the isotopic analyses summarized in Table 4.4.

4.1.6.5 Groundwater

Groundwater wells that supplied drinking water downgradient of PGDP have been replaced with public drinking water and the groundwater is not used as a drinking water source.

4.1.7 Sediment Monitoring and Estimated Dose

Sediment is an important component of the aquatic environment. Radionuclides can be transported by surface as suspended and dissolved constituents. They can adsorb on suspended organic/inorganic solids or be assimilated by plants and animals. Suspended solids, dead biota, and excreta settle to the bottom and potentially impact the bottom-dwelling community of organisms and can play a significant role in aquatic ecological ecosystem by serving as a repository for radioactive substances.

4.1.7.1 Sediment Surveillance Program

Radiological and non-radiological sediment sampling at the Paducah Site was conducted during June 2016. The sampling was conducted at locations chosen to assess areas of public access, introduction of plant effluents to the environment, unplanned releases, and verification of the effectiveness of the PGDP's effluent controls (Figure 4.5) and contaminated sediment removal actions. The sediment concentration results for CY 2016 are similar to those measured during previous years (Table 4.5). Uranium isotope activity was above background activity in Bayou and Little Bayou Creeks in the immediate vicinity and downstream of the PGDP industrial site. Other radionuclides were detectable in trace concentrations that were not significantly above background values presented in Methods for Conducting Risk Assessments and Risk Evaluations (DOE 2016a).

*Table 4.5. CY 2016 Radiological Activities for Sediment Sampling**

Parameter	S1	S2	S2 (duplicate)	S20 (background)	S27	S33	S34
Alpha activity	2.08E+01	9.40E+00	1.08E+01	8.88E+00	1.14E+01	1.05E+01	1.78E+01
Beta activity	1.06E+02	9.66E+00	1.38E+01	1.12E+01	1.79E+01	1.42E+01	2.36E+01
Americium-241	-1.32E-02[b]	1.50E-01[b]	8.01E-02[b]	9.63E-02[b]	-1.56E-02[b]	4.04E-02[b]	1.62E-01[b]
Cesium-137	8.43E-02	1.71E-02[b]	-7.97E-03[b]	1.06E-02[b]	-5.73E-03[b]	-1.57E-02[b]	2.11E-02[b]
Neptunium-237	-6.72E-02[b]	4.24E-02[b]	2.42E-02[b]	-5.55E-02[b]	-2.42E-02[b]	-3.63E-02[b]	1.38E-01[b]
Plutonium-238	2.99E-02[b]	4.11E-02[b]	3.48E-02[b]	3.60E-02[b]	5.15E-02[b]	1.12E-01[b]	2.09E-02[b]
Plutonium-239/240	3.22E-02[b]	5.86E-02[b]	-8.93E-02[b]	1.05E-01[b]	3.52E-02[b]	0.00E+00[b]	3.20E-01[b]

Technetium-99	1.75E+01	1.97E+00[b]	6.67E-01[b]	1.12E+00[b]	2.18E+00[b]	1.60E+00[b]	1.66E+00[b]
Thorium-230	1.01E+00	7.82E-01	1.06E+00	1.46E+00	9.72E-01	1.08E+00	8.62E-01
Total Uranium	1.75E+01	8.74E+00	1.10E+01	1.81E+00	2.30E+00	2.16E+00	8.53E+00
Uranium-234	4.24E+00[b]	1.26E+00[b]	1.30E+00	8.99E-01[b]	1.27E+00[b]	7.87E-01[b]	1.21E+00[b]
Uranium-235	1.52E-01	4.40E-02	5.41E-02	2.79E-02	3.61E-02	3.94E-02	6.16E-02
Uranium-238	5.92E+00	2.96E+00	3.74E+00	6.12E-01	7.75E-01	7.28E-01	2.89E+00

[a] Units are in pCi/g for all, except Total Uranium. Total Uranium units are in mg/kg.
[b] Result reported at concentrations less than the laboratory's reporting limit.

4.1.7.2 Sediment Dose

The sediment dose to the hypothetical MEI assumes potential exposure to contaminated sediment in Bayou and Little Bayou Creeks during hunting, fishing and other recreational activities. Exposure is assumed to occur through incidental ingestion of 100 mg/day contaminated sediment at one creek location every other day during the hunting season (104 days/year). Exposure calculations for sediment include the ingestion, inhalation, and external gamma pathways. The downstream location with the maximum dose is assumed to represent the dose received from this pathway by the MEI for the sediment pathway. The highest annual sediment exposure pathway dose was calculated at Bayou Creek location S1 (0.062 mrem/yr) downstream of the PGDP (Table 4.6) at the Bayou Creek and Outfall 001 confluence. The sediment exposure pathway is the major contributor to the dose received by the MEI (Table 4.6).

Table 4.6. CY 2016 Average Annual Dose Estimates for 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]	4.15E-04	2.13E-03	0.00E+00	8.72E-05	2.77E-04	1.31E-05	3.30E-03	4.14E-04	1.16E-03	4.64E-03	1.24E-02
S1[b]	0.00E+00	1.48E-02	0.00E+00	0.00E+00	0.00E+00	1.91E-04	0.00E+00	1.54E-03	5.15E-03	4.02E-02	***6.19E-02***
S2[b]	8.08E-05	0.00E+00	2.03E-03	4.72E-06	0.00E+00	2.32E-06	0.00E+00	1.76E-04	8.78E-04	2.07E-02	2.39E-02
S27[b]	0.00E+00	0.00E+00	0.00E+00	3.75E-05	0.00E+00	1.24E-05	0.00E+00	1.71E-04	3.40E-04	1.23E-03	1.79E-03
S33[b]	0.00E+00	0.00E+00	0.00E+00	1.84E-04	0.00E+00	5.60E-06	0.00E+00	0.00E+00	4.77E-04	8.79E-04	1.55E-03
S34[b]	2.83E-04	2.11E-03	8.41E-03	0.00E+00	5.67E-04	6.30E-06	0.00E+00	1.43E-04	1.40E-03	1.73E-02	3.02E-02
Net Exposure from Paducah Site to the Maximally Exposed Individual[a,b,c,d] (Downstream Little Bayou) =											**6.2E-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 2016a), 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.

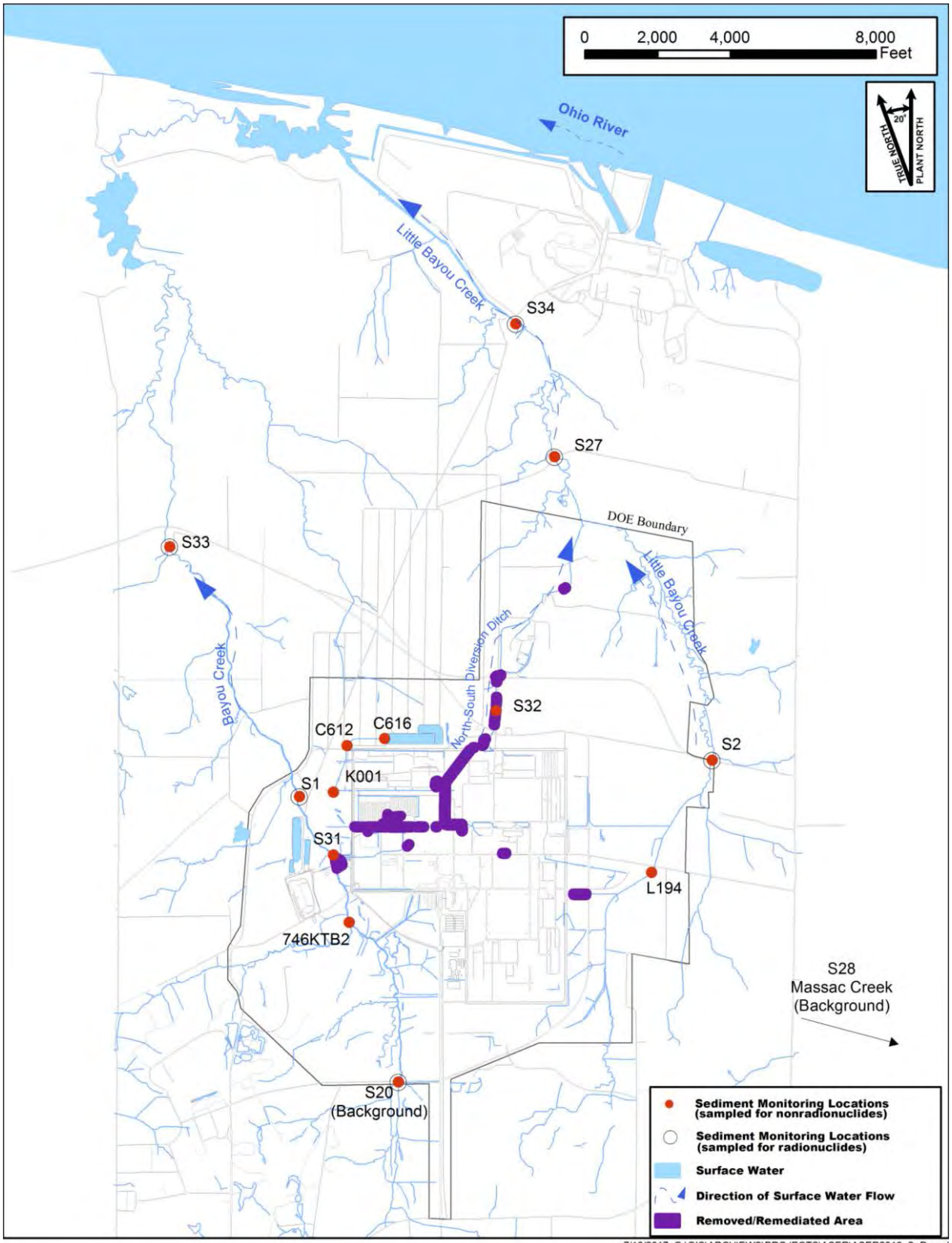


Figure 4.5 PGDP sediment monitoring locations

4.1.8 Terrestrial Environment Monitoring and Estimated Dose

As part of PGDP environmental surveillance the ingestion of contaminated wildlife and farm-raised animal meat, eggs, and milk is evaluated as a pathway for exposure through animal ingestion of contaminated water, sediment, other animals, or direct contact with contaminated areas. Irrigation and deposition through waterborne radionuclides is an incomplete pathway because municipal water is supplied to nearby residents for household and agricultural use. The estimated dose for these pathways is included with the calculations for airborne releases addressed in Section 4.1.1.

4.1.9 Wildlife

Deer monitoring has been eliminated from the Paducah Site monitoring program. This exposure route and its associated dose are assessed through airborne release food chain models discussed in Section 4.1.5.

4.1.10 Direct Radiation Monitoring and Estimated Dose

4.1.10.1 Direct Radiation Surveillance

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. 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 pose the largest potential dose to the public because of their proximity to the PGDP industrial area security fence. Thermoluminescent dosimeters (TLDs) were placed at direct radiation surveillance locations and were collected quarterly and analyzed throughout 2016 (Figure 4.6).

Direct radiation monitoring results indicate that 14 of 51 locations were consistently above background levels and most of the locations were in the vicinity of UF_6 cylinder storage yards and the PGDP industrial area security fence (FPDP 2017d). Security protocols prohibit the public from gaining prolonged access to the PGDP industrial area fence. Therefore, the potential radiation doses in close proximity to the fence were not considered a significant contributor to the public dose.

4.1.10.2 Direct Radiation Dose

Due to Paducah Site security protocols in CY 2016, no members of the public were routinely allowed near the security fence. The external radiation doses measured by TLDs in areas accessible to the public were not statistically above background. Therefore, the possible contribution to public dose are considered to be negligible.

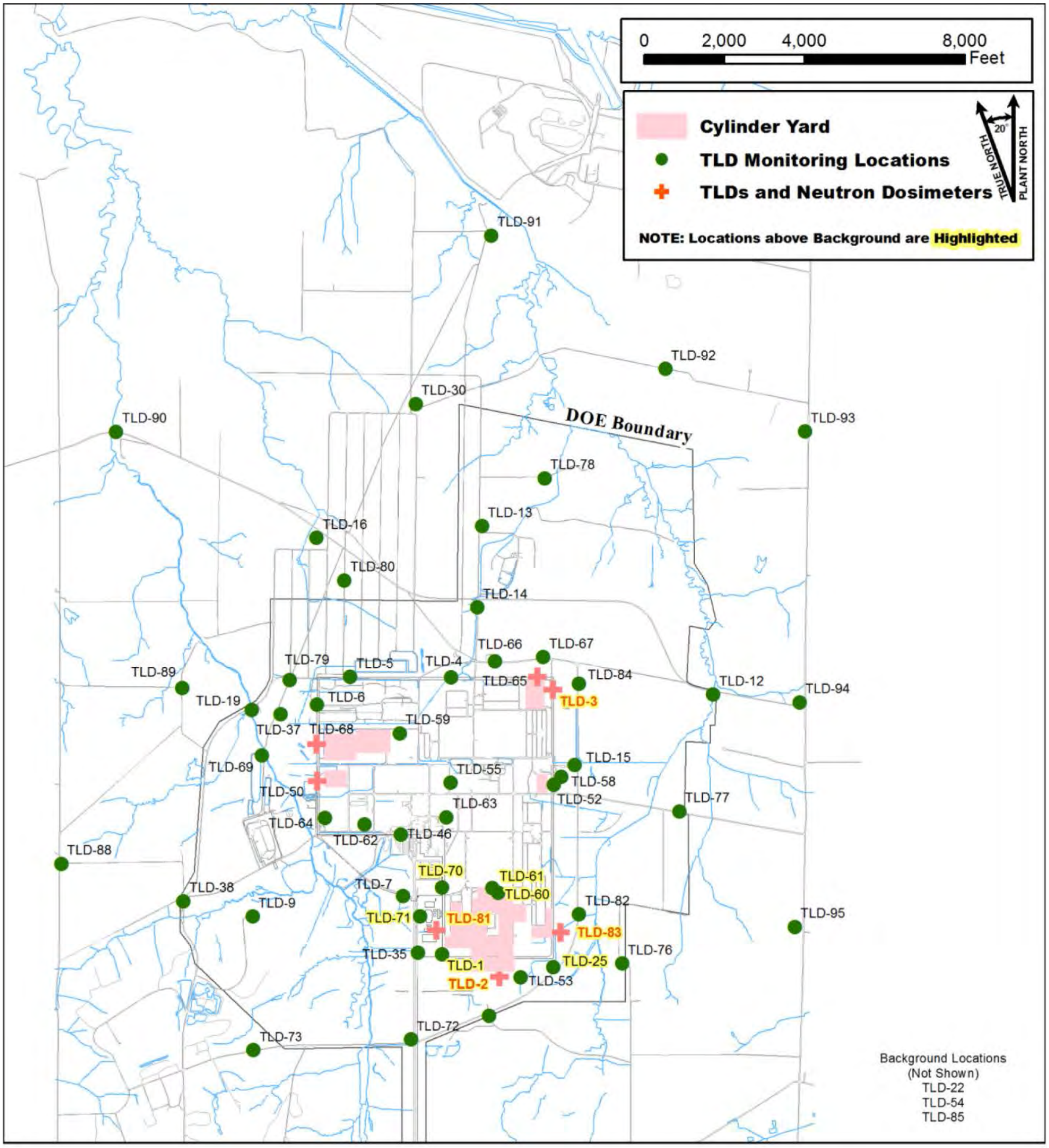


Figure 4.6 TLD direct radiation exposure sampling surveillance locations.

4.1.10.3 Cumulative Dose Calculation

Individuals in the surrounding population could receive dose from atmospheric emissions releases, liquid releases, incidental ingestion of sediments and direct radiation exposure related to PGDP sources. Table 4.7 provides a summary of the cumulative PGDP 2016 radiological dose that could be received by a member of the public as represented by the hypothetical MEI. The groundwater pathway representing contaminated groundwater from DOE sources was not included because DOE provides potentially impacted residents with public water through its Water Policy program. The largest contributor to the cumulative dose is direct exposure.

The combined (internal and external) dose to the MEI was calculated to be 4.5 mrem/yr, well below the DOE annual dose limit of 100 mrem/year to members of the public. The airborne releases to the MEI was calculated to be 0.0013 mrem/year which is well below the EPA airborne dose limit of 10 mrem/year to the public (Table 4.7).

*Table 4.7. Summary of Potential Radiological Dose to the MEI from the Paducah Site for CY 2016**

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]	1.3E-04	0.00013%	9.1E-04	~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	1.9E-01	0.19%	[g]	[g]
Sediments (incidental ingestion)	6.2E-02	0.062%	[g]	[g]
Direct radiation	4.2E+00	4.2%	6.4E-01[h]	150
All Relevant Pathways[a]	4.5E+00[b]	4.5%	8.9E-01	

[a] Pathways defined in previous sections.
[b] Maximum allowable exposure from all sources is 100 mrem/year (DOE Order 458.1).
[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.

Table 4.7 includes the cumulative population dose calculation to members of the public residing within 50 miles of the Paducah Site. Population dose was calculated for each exposure pathway (column 4 'Estimated Collective') and was summed to determine the cumulative population dose from relevant pathways. The annual cumulative population dose, based on representative assumptions, is 0.89 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 natural and man-made sources may be found in environmental media such as water, sediments, and soils. Contaminants may bio accumulate in animals from eating contaminated feed, drinking contaminated water, and breathing contaminated air. Contaminants may bio accumulate in fish when they eat contaminated foods or live in 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 measured concentrations associated with radionuclides of concern at the Paducah Site in animals and fish are low, routine site-specific pathway assessments that include biota sampling, are not performed. Biota in the watersheds have been sampled extensively in the past to the point that further collection of aquatic organisms could pose a negative impact on populations in the aquatic community.

4.1.11.2 Biota Dose

Methods in the DOE Technical Handbook "*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 2016 operations. Doses were assessed for compliance with: 1) the limit in DOE Order 458.1 for native aquatic animal organisms (1 rad/day); 2) the thresholds for terrestrial plants (1 rad/day); and 3) the thresholds for terrestrial animals (0.1 rad/day). The RESRAD-BIOTA computer model is a calculation tool approved by DOE for implementing the technical standard and compares existing radionuclide concentration data from environmental sampling with biota concentration guideline (BCG) screening values to estimate upper bounding doses to biota.

Dose to biota was evaluated for Bayou and Little Bayou Creeks (Figures 4.4 and 4.5). Locations L5 and S1 were sampled to represent water and sediment, respectively in Bayou Creek. Data obtained from L11 and a co-located sediment sample, S27 were used to represent water and sediment in Little Bayou Creek.

Data from water and sediment sampling locations on Bayou and Little Bayou Creeks was entered into the RESRAD-BIOTA computer model to calculate dose to biota from Paducah Site operations. The value for each radionuclide was divided by its corresponding BCG to calculate a partial fraction for each nuclide in each medium. Partial fractions for each medium were added to produce a sum of fractions. Exposures from the aquatic pathway may be assumed to be less than the aquatic dose limit from DOE Order 458.1 if the sum of fractions for the water plus that for the sediment is less than 1.0.

A screening was conducted using the maximum radionuclide concentrations from surface water and sediment samples. Table 4.8 summarizes the radiological dose to aquatic and terrestrial biota for Bayou Creek. Table 4.10 summarizes the radiological dose to aquatic and terrestrial biota for Little Bayou Creek. The sum of fractions for each assessment was less than 1.0, indicating that the applicable BCGs were met for both the aquatic and terrestrial evaluations.

Table 4.8. Bayou Creek CY 2016 Evaluation of Dose to Aquatic and Terrestrial Biota

	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	-1.13E+00 [c]	6.80E+05	-1.66E-06	No	-1.66E-06
Cs-137	-8.88E-01 [c]	1.05E+03	-8.48E-04	No	8.43E-02	4.93E+04	1.71E-06	No	-8.46E-04
K-40	-8.54E+00 [c]	2.90E+03	-2.95E-03	No	N/A	5.79E+04	N/A	No	-2.95E-03
Np-237	-8.54E+00 [c]	6.85E+01	-1.25E-01	Yes	-8.54E-02 [c]	7.86E+04	-1.09E-06	No	-1.25E-01
Pu-238	-1.34E-01 [c]	1.76E+02	-7.61E-04	Yes	2.99E-02 [c]	3.95E+06	7.58E-09	No	-7.61E-04
Pu-239	3.53E-02 [c]	1.87E+02	1.89E-04	Yes	3.22E-02 [c]	7.05E+06	4.57E-09	No	1.89E-04
Tc-99	5.77E+01 [c]	2.47E+06	2.34E-05	No	1.75E+01	4.59E+05	3.81E-05	No	6.15E-05
Th-230	N/A	2.57E+03	N/A	Yes	1.01E+00	2.74E+06	3.68E-07	No	3.68E-07
Th-234	1.17E+02 [c]	2.66E+05	4.40E-04	Yes	N/A	4.32E+04	N/A	No	4.40E-04
U-234	3.46E-01 [c]	2.02E+02	1.71E-03	Yes	N/A	3.03E+06	N/A	No	1.71E-03
U-235	0.00E+00 [c]	2.18E+02	N/A	Yes	N/A	1.10E+05	N/A	No	0.00E+00
U-238	3.46E-01 [c]	2.24E+02	1.55E-03	Yes	N/A	4.29E+04	N/A	No	1.55E-03
Summed	-	-	-1.25E-01	-	-	-	3.75E-05	-	-1.25E-01
	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	-1.13E+00 [c]	5.15E+03	-2.20E-04	Yes	-2.20E-04
Cs-137	-8.88E-01 [c]	4.27E+01	-2.08E-02	Yes	8.43E-02	3.13E+03	2.70E-05	Yes	-2.08E-02
K-40	-8.54E+00 [c]	2.49E+02	-3.42E-02	Yes	N/A	4.42E+03	N/A	Yes	-3.42E-02
Np-237	-8.54E+00 [c]	1.16E+04	-7.37E-04	No	-8.54E-02 [c]	7.63E+03	-1.12E-05	Yes	-7.49E-04
Pu-238	-1.34E-01 [c]	5.51E+02	-2.43E-04	No	2.99E-02 [c]	5.73E+03	5.22E-06	Yes	-2.38E-04

Pu-239	3.53E-02 [c]	6.22E+02	5.67E-05	No	3.22E-02 [c]	5.87E+03	5.49E-06	Yes	6.22E-05
Tc-99	5.77E+01 [c]	6.67E+05	8.65E-05	Yes	1.75E+01	4.14E+04	4.23E-04	Yes	5.09E-04
Th-230	N/A	1.39E+04	N/A	No	1.01E+00	1.04E+04	9.69E-05	Yes	9.69E-05
Th-234	1.17E+02 [c]	3.80E+06	3.08E-05	No	N/A	4.32E+03	N/A	Yes	3.08E-05
U-234	3.46E-01 [c]	6.84E+02	5.06E-04	No	N/A	5.27E+03	N/A	Yes	5.06E-04
U-235	0.00E+00 [c]	7.37E+02	N/A	No	N/A	3.79E+03	N/A	Yes	0.00E+00
U-238	3.46E-01 [c]	7.57E+02	4.57E-04	No	N/A	2.49E+03	N/A	Yes	4.57E-04
Summed	-	-	-5.49E-02	-	-	-	3.26E-04	-	-5.46E-02

Summed total ratio for limiting organism: 4.53E-03.
Summed water ratio for limiting organism: 3.98E-03.
Summed sediment ratio for limiting organism: 5.57E-04.
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 2016 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.

Table 4.9. Little Bayou Creek CY 2016 Evaluation of Dose to Aquatic and Terrestrial Biota

	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	0.00E+00	No	-1.56E-02 [c]	5.15E+03	-3.03E-06	Yes	-3.03E-06
Cs-137	N/A	4.27E+01	0.00E+00	Yes	-5.73E-03 [c]	3.13E+03	-1.83E-06	Yes	-1.83E-06
Np-237	N/A	1.16E+04	0.00E+00	No	-2.42E-02 [c]	7.63E+03	-3.17E-06	Yes	-3.17E-06
Pu-238	N/A	5.51E+02	0.00E+00	No	5.15E-02 [c]	5.73E+03	8.99E-06	Yes	8.99E-06
Pu-239	N/A	6.22E+02	0.00E+00	No	3.52E-02 [c]	5.87E+03	6.00E-06	Yes	6.00E-06
Tc-99	3.45E+01 [c]	6.67E+05	5.17E-05	Yes	2.18E+00 [c]	4.14E+04	5.27E-05	Yes	1.04E-04
Th-230	-6.74E-02 [c]	1.39E+04	-4.86E-06	No	9.72E-01	1.04E+04	9.32E-05	Yes	8.84E-05
U-234	3.25E-02 [c]	6.84E+02	4.75E-05	No	N/A	5.27E+03	0.00E+00	Yes	4.75E-05
U-235	2.53E-01 [c]	7.37E+02	3.43E-04	No	N/A	3.79E+03	0.00E+00	Yes	3.43E-04
U-238	5.25E-01 [c]	7.57E+02	6.94E-04	No	N/A	2.49E+03	0.00E+00	Yes	6.94E-04
Summed	-	-	1.13E-03	-	-	-	1.53E-04	-	1.28E-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	0.00E+00	No	-1.56E-02	3.65E+25	-4.27E-28	No	-4.27E-28
Cs-137	N/A	5.99E+05	0.00E+00	No	-5.73E-03	3.65E+25	-1.57E-28	No	-1.57E-28
Np-237	N/A	6.49E+06	0.00E+00	No	-2.42E-02	3.65E+25	-6.63E-28	No	-6.63E-28
Pu-238	N/A	1.89E+05	0.00E+00	No	5.15E-02	3.65E+25	1.41E-27	No	1.41E-27
Pu-239	N/A	2.01E+05	0.00E+00	No	3.52E-02	3.65E+25	9.64E-28	No	9.64E-28
Tc-99	3.45E+01 [c]	1.54E+07	2.24E-06	No	2.18E+00	3.65E+25	5.97E-26	No	2.24E-06
Th-230	-6.74E-02 [c]	4.52E+05	-1.49E-07	No	9.72E-01	3.65E+25	2.66E-26	No	-1.49E-07
U-234	3.25E-02 [c]	4.05E+05	8.03E-08	No	0.00E+00	3.65E+25	0.00E+00	No	8.03E-08
U-235	2.53E-01 [c]	4.20E+05	6.02E-07	No	0.00E+00	3.65E+25	0.00E+00	No	6.02E-07
U-238	5.25E-01 [c]	4.06E+05	1.29E-06	No	0.00E+00	3.65E+25	0.00E+00	No	1.29E-06
Summed	-	-	4.07E-06	-	-	-	8.75E-26	-	4.07E-06
	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	0.00E+00	No	-1.56E-02 [c]	3.65E+26	-4.27E-29	No	-4.27E-29
Cs-137	N/A	4.93E+07	0.00E+00	No	-5.73E-03 [c]	3.65E+26	-1.57E-29	No	-1.57E-29
Np-237	N/A	7.86E+07	0.00E+00	No	-2.42E-02 [c]	3.65E+26	-6.63E-29	No	-6.63E-29
Pu-238	N/A	3.95E+09	0.00E+00	No	5.15E-02 [c]	3.65E+26	1.41E-28	No	1.41E-28
Pu-239	N/A	7.05E+09	0.00E+00	No	3.52E-02 [c]	3.65E+26	9.64E-29	No	9.64E-29
Tc-99	3.45E+01 [c]	4.59E+08	7.52E-08	No	2.18E+00 [c]	3.65E+26	5.97E-27	No	7.52E-08

Th-230	-6.74E-02[c]	2.74E+09	-2.46E-11	No	9.72E-01	3.65E+26	2.66E-27	No	-2.46E-11
U-234	3.25E-02[c]	3.03E+09	1.07E-11	No	N/A	3.65E+26	0.00E+00	No	1.07E-11
U-235	2.53E-01[c]	1.10E+08	2.31E-09	No	N/A	3.65E+26	0.00E+00	No	2.31E-09
U-238	5.25E-01[c]	4.29E+07	1.22E-08	No	N/A	3.65E+26	0.00E+00	No	1.22E-08
Summed	-	-	8.97E-08	-	-	-	8.75E-27	-	8.97E-08

Summed total ratio for limiting organism: 3.88E-03.
Summed water ratio for limiting organism: 3.72E-03.
Summed sediment ratio for limiting organism: 1.61E-04.
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 2016 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.

4.2 Clearance of property containing residual radioactive material

This section addresses clearance of personal property (see glossary definition) containing residual radioactive material. The Paducah Site has begun efforts to transfer real property (see glossary definition), but clearance of real property has not taken place as of CY 2016.

DOE contractors use the processes, guidelines, and release limits found in DOE Order 458.1 and associated guidance for the clearance of residual radioactive material. Surface Contaminated Object Limits are used for clearance of objects with the potential for surface contamination. Specific Authorized Limits have been derived to control whether items with potential volumetric contamination are released (Table 4.10). When volumetric Authorized Limits have not been established, release is determined based on a comparison to established background radionuclide concentrations or approved release limits.

Property potentially containing radioactive material will not be cleared from the Paducah Site unless the property is demonstrated not to contain background or residual radioactive material. The property is evaluated and appropriately monitored or surveyed to determine that residual radioactive material levels are within approved release limits.

In 2016, SST authorized 311 releases of personal property. The property was surveyed for surface contamination and included, but was not limited to, vehicles, mowers, miscellaneous equipment and parts, furniture, electronics, and fire extinguishers.

DOE contractor FPDP shipped 5,000 cubic feet of lube and transformer oil meeting authorized limits to the Clean Harbors facility in Texas. Approximately 955 tons of waste meeting authorized limits was disposed of in the C-746-U Landfill during 2016 which included demolition debris.

Disposal of materials meeting authorized limits criteria began at the C-746-U Landfill in 2003. Table 4.10 identifies the radionuclide (Isotope), the activity (Activity) of each radionuclide that was disposed, the total activity of each radionuclide disposed at C-746-U since 2003, the authorized limit (Source Term Limit) and the percent of the C-746-U authorized limit utilized through 2016.

Table 4.10. CY 2016 C-746-U Landfill Authorized Limit Disposals

Cumulative Activity from 2016 Disposal			**Total Activity from Disposal 5/21/03 to 12/31/16**		
Isotope	**Activity (Curies)**		**Activity (Curies)**	**Source Term Limit (Curies)**	**Percent Utilized***
Americium-241	7.27E-05		1.09E-02	79	0.01%
Cesium-137	1.14E-04		1.20E-02	43	0.03%
Neptunium-237	2.06E-04		1.34E-02	12	0.11%

Plutonium-238	1.05E-04		4.64E-03	88	0.01%
Plutonium-239/240	1.18E-04		2.40E-02	162	0.01%
Technetium-99	1.38E-02		1.31E+00	117	1.12%
Thorium-228	1.17E-03		7.60E-02	9	0.84%
Thorium-230	1.68E-03		2.39E-01	230	0.10%
Thorium-232	8.81E-04		7.63E-02	9	0.85%
Uranium-234	9.13E-03		3.95E-01	360	0.11%
Uranium-235	5.18E-04		1.85E-02	15	0.12%
Uranium-238	2.10E-02		4.28E-01	360	0.12%

Waste streams added (2016)	6	Waste streams disposed of (2003–2016)	246
Mass disposed of (2016)	955 tons	Mass disposed of (2003–2016)	121,000 tons
		Volume of current cells	386,169 yd^3
		Remaining cell volume	68,680 yd^3

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

In 2016, FPDP authorized 888 releases of personal property following assessment for contamination. Several of these releases were in support of reuse and recycling efforts and deactivation operations. Multiple radiological surveys were performed to measure and assess the radiological status of the property. Released items included but were not limited to: heavy equipment, vehicles, containers, tanks, monitoring equipment, activated carbon and batteries. 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 compared to established background concentrations or approved release limits.

4.3 Unplanned Radiological Releases

There were no unplanned radiological releases at the PGDP in 2016.

5.0 ENVIRONMENTAL NONRADIOLOGICAL PROGRAM

5.1 Air Monitoring

Steam plant emissions were the largest permitted non-radiological point source at this site until 2015 when the steam plant was replaced by natural gas fired boilers which do not require monitoring.

5.2 Surface Water Monitoring

At the Paducah site, CWA regulations were complied with through issuance of a KPDES permits for discharges to Bayou Creek and Little Bayou Creek. Surface water locations and the monitoring program at the Paducah site are listed in Table 5.1 and Figure 4.4. CY 2016 non-radiological surface water sample results are summarized in Table 5.2.

5.3 Sediment Monitoring

Total PCBs were detected in sediment during 2016. Detections ranged from 1.76 µg/kg to 477 µg/kg. Total PCB concentrations were within the acceptable risk range bounded by a recreational user no action and action levels. The PCB no action level is 179 ug/kg and the action level is 17,900 ug/kg (DOE 2016a).

Table 5.1. CY 2016 PGDP Surface Water Monitoring Summary.

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 2016 (January–March) Second Quarter 2016 (April–June) Third Quarter 2016 (July–September) Fourth Quarter 2016 (October–December)	L135, L136, L154*
C-746-U Landfill Surface Water *Quarterly Compliance Monitoring Reports*: First Quarter 2016 (January–March) Second Quarter 2016 (April–June) Third Quarter 2016 (July–September) Fourth Quarter 2016 (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 2016 (Data reported January–June 2016) First Half of FY 2017 (Data reported July–December 2016)	C001

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

Table5.2. Ranges of Detected Analytes in 2014 Surface Water Samples.

Analyte	Range
Anions	
Chloride (µg/L)	121–66,700
Nitrate as Nitrogen (µg/L)	661–4,040
Sulfate (µg/L)	151–52,800
Wet Chemistry Parameters	
Carbonaceous Biochemical Oxygen Demand (µg/L)	1,040–76,500
Chemical Oxygen Demand (µg/L)	14,400–185,000
Dissolved Solids (µg/L)	52,900–303,000
Fecal Coliform (CFU/100 mL)	1–33
Fecal Coliform (col/100 mL)	1–29
Hardness—Total as $CaCO_3$ (µg/L)	47,500–582,000
Suspended Solids (µg/L)	600–152,000
Total Organic Carbon (µg/L)	9,690–23,500
Total Solids (µg/L)	91,000–323,000
Semivolatile Organic Compounds	
Indeno(1,2,3-cd)pyrene (µg/L)	0.052–0.052
Volatile Organic Compounds	
Trichloroethene (µg/L)	0.32–6.13

Analyte	Range
Pesticides/PCBs	
PCB-1242 (µg/L)	0.0347–0.0623
PCB-1248 (µg/L)	0.0385–0.981
PCB-1254 (µg/L)	0.057–0.381
PCB-1260 (µg/L)	0.0473–0.142
Total PCBs (µg/L)	0.0347–1.36
Other Organics	
Oil and Grease (µg/L)	1,120–2,770
Metals	
Antimony (µg/L)	1.05–1.05
Arsenic (µg/L)	1.89–3.8
Chromium (µg/L)	2.03–15
Copper (µg/L)	0.464–8.29
Iron (µg/L)	36–3,960
Lead (µg/L)	0.501–1.06
Nickel (µg/L)	0.525–7.01
Phosphorous (µg/L)	29.2–906
Sodium (µg/L)	646–33,100
Thallium (µg/L)	0.485–01.38
Uranium (µg/L)	0.13–423
Zinc (µg/L)	3.76–82.1

5.4 Biota Monitoring

Biological monitoring (fish or benthic macroinvertebrate sampling) was not required by KPDES permits that were in place during 2016.

5.5 Aquatic Life

Aquatic or biological monitoring of Bayou Creek and Little Bayou Creek has been conducted following best management practices (BMPs) and guidelines in the PGDP Watershed Monitoring Plan. KDOW issued a new KPDES permit in 2009 eliminating required fish and macroinvertebrate sampling based on results of years of previous sampling where results indicated no concerns were present. Chronic and acute toxicity sampling remain a KPDES permit condition.

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

5.6 Fire Protection Management and Planning

Wildfire hazard at the PGDP is managed under a Wildland Fire Management Plan. The Wildland Fire Management Plan outlines the coordination of firefighting and emergency response organizations responsible for the DOE reservation and surrounding areas.

5.7 Recreational Hunting and Fishing

A license agreement between the Kentucky Department of Fish and Wildlife Resources and the DOE was renewed in 2016 to allow use of DOE-owned lands in the WKWMA for recreational, hunting and fishing activities.

6.0 Groundwater Protection Program

The Regional Gravel Aquifer (RGA) is the shallowest unit of usable groundwater underlying the PGDP and its immediate vicinity. The RGA is the aquifer tapped for local agriculture and domestic groundwater use (Figure 6.1). The primary contaminants identified in groundwater underlying the PGDP and adjacent land are TCE and Tc-99 which are related to historical PGDP industrial activities. TCE was used until 1993 as an industrial degreasing solvent to routinely clean miles of piping and equipment from the uranium enrichment process. Tc-99 is a radioactive nuclear fission by-product that arrived at the PGDP when used reactor fuel rods (reactor returns) were recycled for re-enrichment. Although reactor returns have not been used in the enrichment process since the 1970's, Tc-99 remains present in PGDP industrial site groundwater and in one of three groundwater plumes related to the site. Known or potential sources of TCE and Tc-99 include former test areas, spills, leaks, buried waste, and leachate derived from contaminated scrap metal that was stored on-site.

Investigations of the on-site TCE groundwater contamination source areas at the PGDP continued in 2016. The main source areas and highest concentrations of TCE in groundwater are near the C-400 Cleaning Building where TCE was delivered by rail in tank cars, transferred, stored and used in large baths to clean process piping and equipment. Spent cleaning-process TCE was discharged through the PGDP sanitary sewer system for transport to the site's waste water treatment facility.

TCE has a low solubility in water and a higher density than water making it a dense non-aqueous phase liquid (DNAPLs). Because of its density DNAPL typically sinks through the subsurface materials and water. Along its path of travel, some DNAPL will remain in interstitial pore spaces (between the grains) of subsurface material and may pool on top of less permeable layers of subsurface materials. It may also pool at the base of materials that make up an aquifer. DNAPLs in subsurface interstitial spaces and pools are a continuous source of TCE contamination within the aquifer as TCE DNAPL dissolves very slowly. In the subsurface and in aquifers, treatment of TCE DNAPL contamination is extremely difficult.

Surveillance monitoring at the PGDP is used to detect the nature and extent of contamination, the types and concentrations of groundwater contaminants and the movement of groundwater. Data obtained from PGDP groundwater monitoring supports the decision-making process regarding the treatment of groundwater contamination and the management and treatment of groundwater contaminant sources. Groundwater compliance monitoring is conducted at the PGDP to ensure that the site is in compliance with environmental and health regulations. Figure 6.2 identifies the surveillance and compliance monitoring wells sampled in 2016 and shows the 2014 TCE plumes associated with the Paducah Site.

6.1 Geologic and Hydrogeological Setting

The local groundwater flow system underlying and surrounding the PGDP is managed and monitored through evaluation of areas with unique subsurface materials that impact how water and contamination are transmitted.

The groundwater flow system at the PGDP consists of the following components (from shallowest to deepest): the Terrace Gravel and Eocene Sand flow system, Upper Continental Recharge System (UCRS), the Regional Gravel Aquifer (RGA), and the McNairy flow system (Figure 6.1). PGDP surface spills, subsurface leaks, and leaching from contaminated wastes in the UCRS have the potential to impact groundwater quality in the RGA. Contaminants travel through silt and clay materials of the UCRS and enter the gravel and sand of the RGA.

RGA groundwater at the PGDP generally flows from south to north. Subsurface groundwater flow originates south of the PGDP in the Terrace Gravel and Eocene Sands. Terrace Gravel groundwater discharges to local streams and recharges the RGA across the southern extent of the PGDP industrial area. Groundwater flow through the UCRS is predominantly downward, also recharging the RGA. RGA groundwater generally flows northward toward the Ohio River, which is the local base level for the RGA system. The McNairy flow system beneath the Paducah Site also flows northward to discharge into the Ohio River.

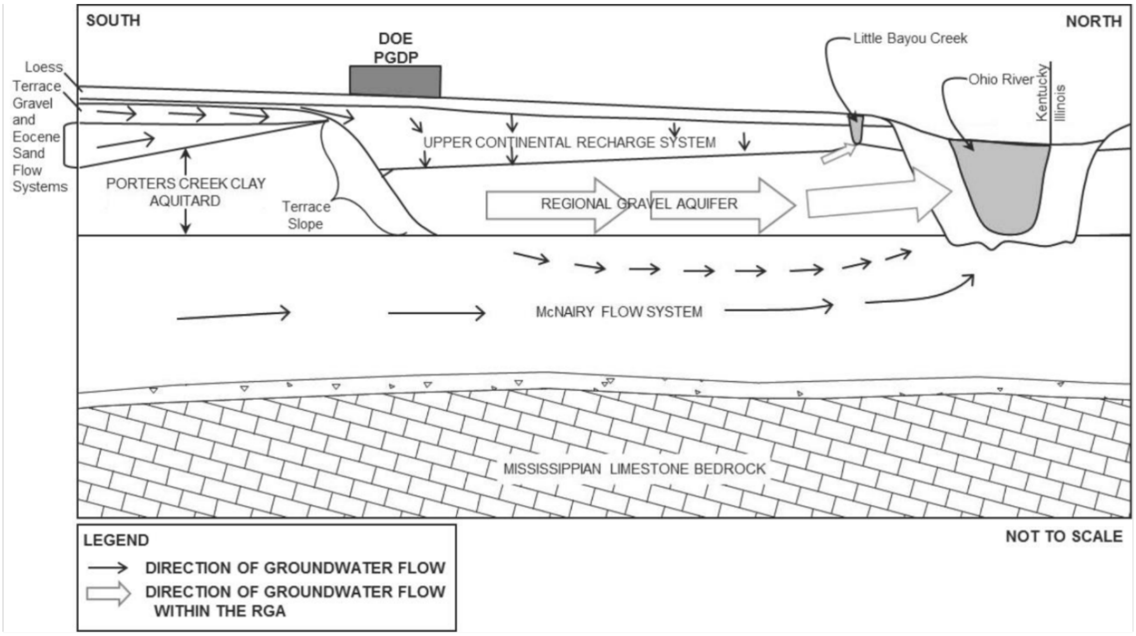


Figure 6.5 Conceptual Diagram of the PGDP subsurface, groundwater flow and the Regional Gravel Aquifer.

6.2 Uses of Groundwater in the Vicinity of PGDP

Only the West Kentucky Wildlife Management Area and some lightly populated farmlands occupy tracts of land in the immediate vicinity of the PGDP. Homes are sparsely located along rural roads. Two communities, Grahamville and Heath, lie east within 2 miles of the plant.

Historically, groundwater was the primary source of drinking water for residents, farms 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. Water is provided through DOE's Water Policy Program. Residential wells in impacted and potentially impacted areas have been capped and locked except for those that are used by DOE for monitoring. Locking, capping and monitoring are conducted under license agreements between DOE and each resident and agreements are renewed every five years.

The PGDP uses surface water from the Ohio River for process waters and on-site drinking water. The nearest community downstream of Paducah using surface water for drinking water is Cairo, 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 PGDP to assess the impacts of plant operations on groundwater quality (Figure 6.2). The primary objective of groundwater monitoring at the Paducah Site is early detection of contamination from past and present PGDP activities. The PGDP approach for site-wide groundwater surveillance, monitoring and compliance is outlined in the PGDP Groundwater Protection Plan and the Paducah Site EMP. During 2016 over 250 monitoring wells and residential water supply wells were sampled

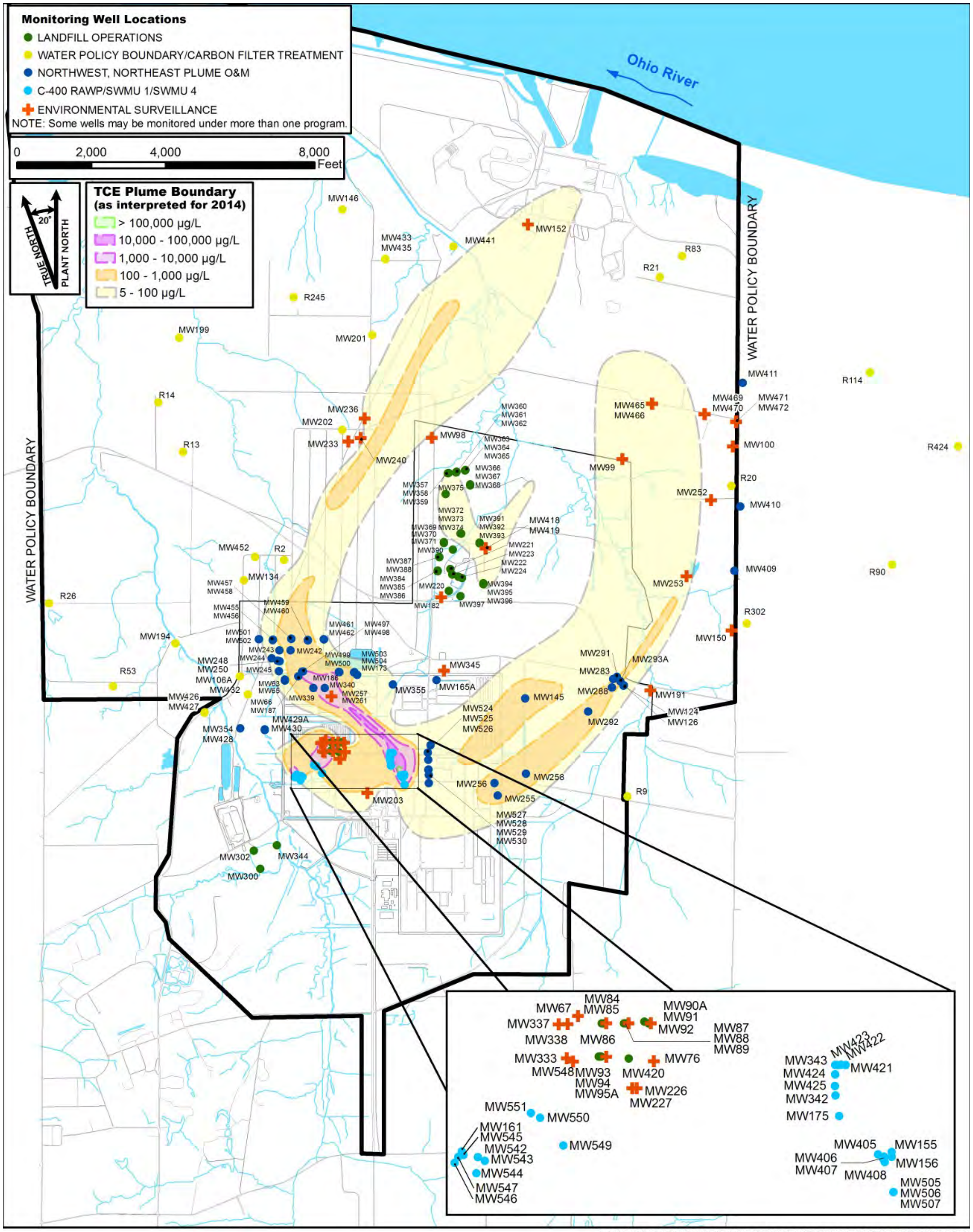


Figure 6.6 2016 PGDP Groundwater surveillance and compliances wells.

Table 6.1 Groundwater monitoring conducted at the PGDP in 2016.

Program and Reporting Location	Number of Wells[a]				
	Terrace Gravel/ Eocene Sands	**RGA**	**Upper Continen-tal Recharge 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 2016 (January–March) Second Quarter 2016 (April–June) Third Quarter 2016 (July–September) Fourth Quarter 2016 (October–December)	0	18	5[b]	0	23[c]
C-746-U Landfill Wells *Quarterly Compliance Monitoring Reports*: First Quarter 2016 (January–March) Second Quarter 2016 (April–June) Third Quarter 2016 (July–September) Fourth Quarter 2016 (October–December)	0	12	9[b]	0	21
C-404 Landfill Wells (required by permit) *Semiannual C-404 Groundwater Monitoring Reports:* C-404 Hazardous Waste Landfill May 2016 Semiannual Groundwater Report (October 2015–March 2016) C-404 Hazardous Waste Landfill November 2016 Semiannual Groundwater Report (April 2016–September 2016)	0	5	4	0	9
C-404 Landfill Wells (noncommitted)	0	11	0	0	11
C-746-K Landfill Wells *Semiannual FFA Progress Reports:* Second Half of FY 2016 (Data reported January–June 2016) First Half of FY 2017 (Data reported July–December 2016)	3	0	0	0	3
Program and Reporting Location	Number of Wells[a]				
	Terrace Gravel/ Eocene Sands	RGA	Upper Continen-tal Recharge System	Rubble Zone	Total
Northeast Plume Operations and Maintenance Program *Semiannual FFA Progress Reports:* (see links above)					
Semiannual Wells	0	9	0	0	9
Quarterly Wells	0	5	0	0	5
Quarterly Optimization Wells	0	7	0	0	7
Northwest Plume Operations and Maintenance Program *Semiannual FFA Progress Reports:* (see links above)					
Semiannual Wells	0	33	0	0	33
C-400 Cleaning Building Interim Remedial Action Monitoring Wells *Semiannual FFA Progress Reports:* (see links above)					
Semiannual Wells	0	8	0	0	8
Quarterly Wells	0	9	0	0	9
SWMU 4 Monitoring Wells *Semiannual FFA Progress Reports:* (see links above)					
Biennial Wells	0	4	0	0	4
SWMU 1 Monitoring Wells *Five-Year Review* (to be reported in 2018)					
Quarterly Wells	0	7	0	0	7
Water Policy Boundary Monitoring Program *Annual Site Environmental Report*					
Northwestern Wells (quarterly)	0	20	0	0	20

Northeastern Wells (annual)	0	7	0	0	7
Carbon Filter Treatment System *Annual Site Environmental Report*	0	1	0	0	1
Environmental Surveillance Groundwater Monitoring Program *Annual Site Environmental Report*					
Annual Wells	0	22	1	1	24
Geochemical Environmental Surveillance	0	38	0	0	38

[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.

in accordance with DOE Orders, Federal, State, and local requirements. Table 6.1 identifies the groundwater monitoring and surveillance programs, number of wells and flow system components for 2016.

6.4 Groundwater Monitoring Results

The Environmental Surveillance Groundwater Monitoring Program was reviewed during CY 2016. CY 2016 groundwater monitoring at the PGDP was conducted at current and inactive landfills (compliance monitoring), groundwater plume pump-and-treat operations (performance monitoring), C-400 Cleaning Building Interim Remedial Action (performance monitoring) and area residential wells (surveillance monitoring). Results are compiled in the Paducah Oak Ridge Environmental Information System (OREIS) database. A summary of detected analytes in 2016 are shown in Table 6.2.

6.5 PGDP Groundwater Contaminant Plumes

PGDP groundwater plume maps are revised every two years to incorporate routine groundwater monitoring and characterization data, demonstrate the progress of groundwater cleanup, and facilitate planning for ongoing groundwater cleanup. Plume maps depict the general footprint of the TCE and Tc-99 contamination in the RGA and convey the general magnitude and distribution of contamination within the plumes. CY 2014 plume maps from the document *Trichloroethene and Technetium-99 Groundwater Contamination in the Regional Gravel Aquifer for Calendar Year 2014 at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (LATA Kentucky 2015a) were the latest plume map revisions as of CY 2016 and are the plume maps in this document.

Table 6.2. Analytes Detected in PGDP Groundwater in CY 2016

Analyte	Range
Anions	
Bromide (µg/L)	93.2–1,270
Chloride (µg/L)	760–117,000*
Fluoride (µg/L)	43.5–596
Nitrate as Nitrogen (µg/L)	35.7–4,920
Sulfate (µg/L)	4,700–780,000
Wet Chemistry Parameters	
Alkalinity (µg/L)	14,800–181,000
Chemical Oxygen Demand (µg/L)	7,000–164,000
Cyanide (µg/L)	2.2–2.2
Dissolved Organic Carbon (µg/L)	818–1,200
Dissolved Solids (µg/L)	130,000–629,000
Iodide (µg/L)	521–779
Sulfide (µg/L)	50.4–50.4
Sulfite (µg/L)	500–500

Analyte	Range
Total Organic Carbon (µg/L)	476–9,390
Total Organic Halides (µg/L)	3.4–601
Volatile Organic Compounds	
1,1,1-Trichloroethane (µg/L)	15.3–15.3
1,1,2-Trichloroethane (µg/L)	1.5–5.69
1,1-Dichloroethane (µg/L)	0.5–17.2
1,1-Dichloroethene (µg/L)	0.73–170*
1,2-Dichloroethane (µg/L)	0.35–0.41
Benzene (µg/L)	0.71–0.77
Carbon tetrachloride (µg/L)	0.32–104
Chloroform (µg/L)	0.3–400
cis-1,2-Dichloroethene (µg/L)	0.32–45,600*
Tetrachloroethene (µg/L)	0.37–2.78
Toluene (µg/L)	0.31–3.11
trans-1,2-Dichloroethene (µg/L)	0.4–10.5*
Trichloroethene (µg/L)	0.3–49,500*
Trichlorotrifluoroethane (µg/L)	40.6–120
Vinyl chloride (µg/L)	0.52–94.8
PCBs	
PCB-1242 (µg/L)	0.0366–0.167
Total PCBs (µg/L)	0.0366–0.167

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

Records of decision are in place at the PGDP to clean up the Northwest Plume, the Northeast Plume, the C-400 Cleaning Building source area, and sources to the Southwest Plume (Figure 6.3). Table 6.3 lists the cumulative TCE removed through all of the plume and plume source area remedial projects. Graphs in Figures 6.4 and 6.5 illustrate the cumulative TCE removed by the NWPGS and the NEPCS. Figure 6.6 shows site preparation to begin implementing the remedy for sources to the Southwest Plume.

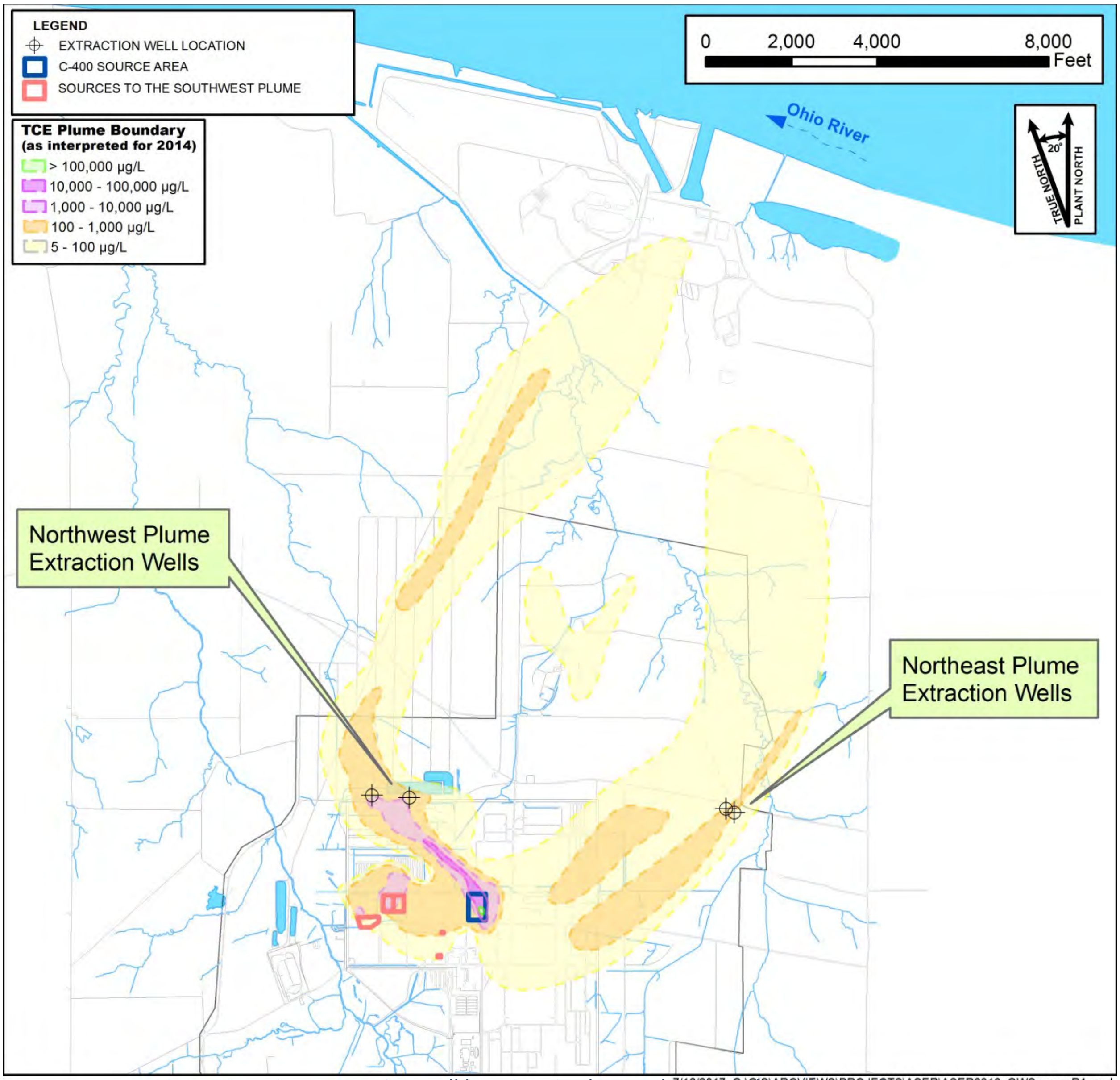
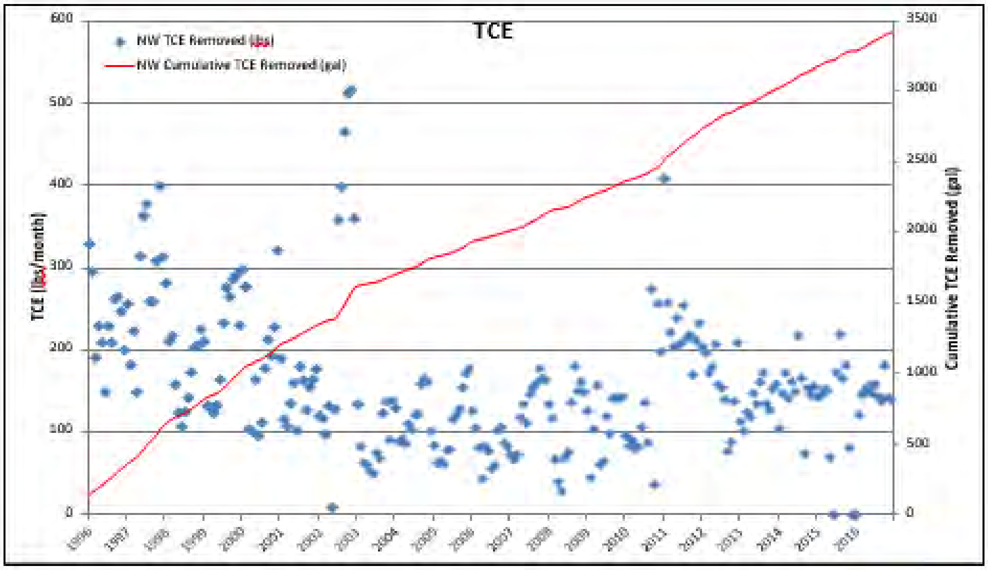


Figure 6.7 PGDP extraction well locations in the Northwest and Northeast Plumes.

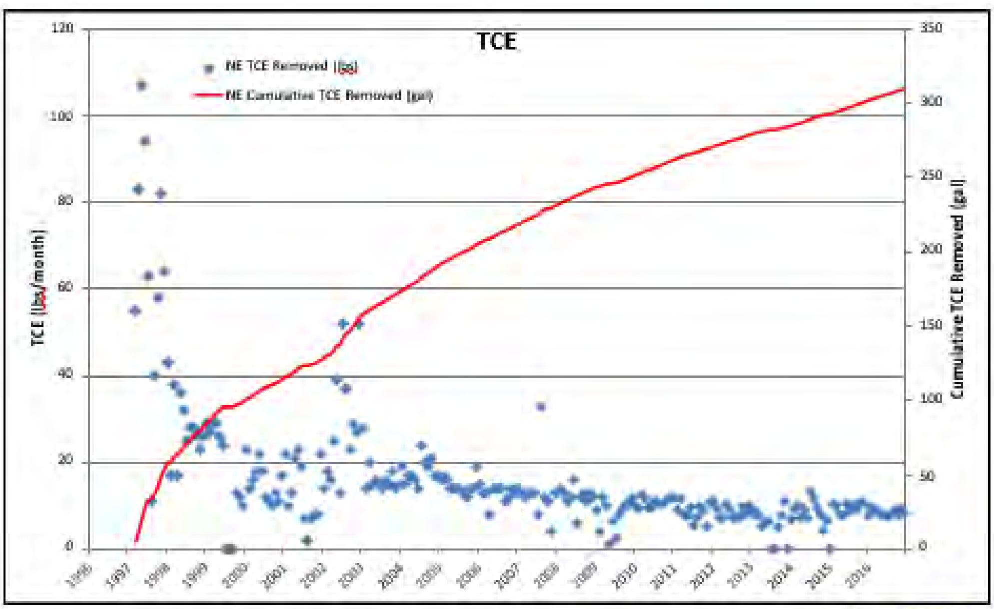
Table 6.3. Cumulative TCE removed from the PGDP subsurface and groundwater by Remedial Actions

Source Area	Cumulative TCE Removed (gal) [a,b]
Northwest Plume Groundwater Treatment System	3,423
Northeast Plume Containment System	310
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



Source: DOE 2017e

Figure 6.8 Cumulative TCE removal for the Northwest Plume Groundwater Treatment System.



Source: DOE 2017e

Figure 6.9 Cumulative TCE removal for the Northeast Plume Groundwater Treatment System

The groundwater maximum contaminant level (MCL) for TCE is 5 ug/L and exceedances of that MCL at the PGDP C-746 landfill complex are listed in Table 6.4. A Groundwater Assessment Report documented that there was no evidence of release from the C-746-U Landfill. The report found that the beta activity (associated with Tc-99) and TCE in the wells were sourced from upgradient of the C-746-U Landfill and associated with migration of historical plumes. Statistical analyses also are used to evaluate compliance MWs at the landfills. Each report (see Table 6.1) lists any statistical exceedance that is found.

Table 6.4. CY 2016 Exceedances of Groundwater MCL's at the C-746 Landfills.

Upper Continental Recharge System	Upper RGA	Lower RGA
C-746-S and C-746-T Landfills		
MW390: beta activity	MW369: beta activity MW372: 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 MW363: trichloroethene MW369: beta activity MW372: trichloroethene	MW358: trichloroethene MW361: trichloroethene MW364: trichloroethene MW370: beta activity MW373: trichloroethene

[a] TCE values include liquid VOCs and recovered VOCs on carbon.
[b] Cumulative through December 31, 2016. Value taken from DOE 2017c.

7.0 Quality Assurance

The accuracy and reproducibility of information generated by the Environmental Monitoring Program is ensured by the Paducah Site Quality Assurance/Quality Control (QA/QC) Program. Technical and regulatory requirements and codes related to accuracy and reproducibility of data are reflected in the QA/QC Program including standards to control equipment use, data collection, and data reporting. Guidelines and requirements reflected in the QA/QC Program include the following:

- DOE Order 414.1D, *Quality Assurance*;
- *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 (ASTM); and
- American Society for Quality Control.

The QA/QC Program sets up controls for equipment, design, documents, data, non-conformances, and records. Program addresses planning, implementing, and assessing activities and implementing effective corrective actions to address QA/QC deficiencies. QA/QC program requirements are included in project-specific QA plans and other planning documents.

The Paducah Site uses the DOE Consolidated Audit Program (DOECAP) audited laboratories. DOECAP implements annual performance qualification audits of environmental analytical laboratories and commercial waste treatment, storage, and disposal facilities to support complex-wide DOE activities. Field forms, inter-personnel communications, sample chain-of-custody, data assessment, and logbooks are maintained according to their respective QA procedures.

7.1 Field Sampling Quality Control

7.1.1 Data Quality Objectives and Sample Planning

When conducting sampling, data quality objectives (DQOs) are utilized to identify the number of samples, the sampling location, methods, schedules, and coordination of samples for a program, project or sampling event. DQOs are documented in the Paducah site EMP.

Each sample is given a specific identification number. A statement of work (SOW) for the analytical laboratory was generated from the Paducah Integrated Data System as DQOs for a project progressed from planning to implementation. The PGDP Project Environmental Measurements System (PEMS) database was used to store sample information data including identification number, location, methods, container, and preservation method. The database is then used to produce labels and chain-of-custody forms for each sample.

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
- ORP (oxidation/reduction potential)
- 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 according to EPA sampling methods. Sample media consist of surface water, groundwater, and sediment. 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 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 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 has a target rate of 5%, or 1 per 20 environmental 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 Field and Laboratory Quality Control Samples.

Field QC Samples	Laboratory QC Samples
Field blanks	Laboratory duplicates
Field duplicates	Reagent blanks
Trip blanks	Matrix spikes
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 or appropriate, EPA's SW-846 methods are used for sample analysis. Other nationally recognized methods such as those from DOE or ASTM may also be used if appropriate. Analytical methods are identified in a statement of work for laboratory services.

7.2.2 Laboratory Quality Control Samples

Laboratory Quality Control Samples are prepared and analyzed by the analytical methods used. If the samples do not meet QC standards, appropriate action according to the analytical method is taken. Typical laboratory QC samples are identified in Table 7.1.

7.2.3 Independent Quality Control

The Paducah Site is required to participate in independent QC programs, and voluntarily participates in independent programs to improve QC. These programs generate data and provide other labs a review of their performance. Data that does not meet the criteria are investigated and documented. EPA and KDOW require a laboratory QA study. Each laboratory performing analyses to demonstrate KPDES permit compliance is required to participate.

7.2.4 Laboratory Audits/Sample and Data Management Organization

Laboratory audits are performed to ensure labs comply with regulations, methods, and procedures. Audited laboratories are included on the DOE-audited listing for use by the PGDP sample and data management organizations. When labs are audited, the audit findings are documented and addressed by the audited laboratory through corrective actions.

7.3 Data Management

7.3.1 Project Environmental Measurements System

Data generated from sampling events is stored in the Project Environmental Management System (PEMS) which is used to manage field-generated data, import laboratory-generated data, and input data qualifiers identified during the data review process. PEMS data is transferred to the Paducah OREIS database for reporting.

7.3.2 Paducah Oak Ridge Environmental Information System

The Paducah Oak Ridge Environmental Information System (OREIS) is the database used to consolidate data generated by the Environmental Monitoring Program including Paducah Site environmental data. This consolidation consists of the activities necessary to prepare the data for users. The data manager is responsible for notifying the project team and other data users of the available data, and this data is then used in reports to external agencies.

7.3.3 Paducah Environmental Geographic Analytical Spatial Information System

Another system that deals with sample data is the PPPO Paducah Environmental Geographic Analytical Spatial Information System (PEGASIS). This system allows access to environmental sampling data and geographic information system features through the Internet. Environmental data loaded to Paducah OREIS has been assessed, verified, and validated – if applicable. Environmental data from Paducah OREIS is loaded into PEGASIS on a monthly basis, https://pegasis.pad.pppo.gov/.

7.3.4 Electronic Data Deliverables

Electronic Data Deliverables (EDDs) are what is requested for all samples analyzed by each laboratory. Discrepancies in data are reported immediately to the laboratory so corrections can be made or new EDDs can be issued. Approximately 10% of the EDDs are checked randomly to verify that the laboratory continues to provide adequate EDDs.

7.3.5 Data Packages

Data packages are requested from labs when data validation is to be performed on certain samples. When data validation is to be performed on specific sampling event or media samples a "forms only" Level III data package is requested from the laboratory. The contents of the data package and the chain-of-custody forms are compared, and discrepancies identified. Discrepancies are reported so corrections can be made.

7.3.6 Laboratory Contractual Screening

Laboratory contractual screening evaluates a set of data against specified requirements to ensure all data is received. The contractual screening includes, but is not limited to, the chain-of-custody form, requested analytes, method used, units, holding times, and achieved reporting limits.

7.3.7 Data Verification, Validation, and Assessment

Data verification helps compare the data set against a standard requirement. It includes contractual screening and other criteria specific to the data. 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. The data assessment process assures that the type, quality, and quantity of data are appropriate for data use. Data assessment follows data verification and data validation (if applicable) and must be performed at a rate of 100% to ensure data are useable. Rejected data are noted in the Paducah OREIS.

REFERENCES

BJC 2006. *Cultural Resources Survey for the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, BJC/PAD-688/R1, Bechtel Jacobs Company LLC, Paducah, KY, March.

COE (U.S. Army Corps of Engineers) 1994. *Environmental Investigations at the Paducah Gaseous Diffusion Plant and Surrounding Area, McCracken County, Kentucky*, Five Volumes, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

Price, Steven J. and Kreher, Timothy. *Amphibian Habitat Assessment at the Paducah Gaseous Diffusion Plant and the West Kentucky State Wildlife Management Area*, University of Kentucky Center for Applied Energy Research – Kentucky Research Consortium for Energy and Environment, January 2016.

SST (Swift & Staley Team) 2016. *Fiscal Year 2017 Site Sustainability Plan, Paducah Gaseous Diffusion Plant,* SSI.SSPP-0001/R6, Swift & Staley Team, Paducah, KY, December.

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

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

DOC (U.S. Department of Commerce) 2016. McCracken County Quick Facts from the U.S. Census Bureau, http://www.census.gov/quickfacts/table/PST045215/21145,2158836 (accessed March 8, 2016).

DOE 2016a. *Methods for Conducting Risk Assessments and Risk Evaluations at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky,* DOE/LX/07-0107&D2/R7, Volume 1, *Human Health,*

U.S. Department of Energy, Paducah, KY, June.

DOE 2016b. *Community Relations Plan under the Federal Facility Agreement at the Paducah Gaseous Diffusion Plant*, DOE/LX/07-2401&D2/R1, U.S. Department of Energy, Paducah, KY, May.

DOE 2017a. "2016 Site Treatment Plan Annual Update for the U.S. Department Of Energy, Paducah Gaseous Diffusion Plant, Paducah, Kentucky, and the Paducah Site Treatment Plan Waste Minimization Progress Report," PPPO-02-4071106-17 Jennifer Woodard, Paducah Site Lead to Mr. Anthony R. Hatton, Director, Kentucky Department for Environmental Protection, U.S. Department of Energy, March 15.

DOE 2017c. *U.S. Department of Energy Paducah Gaseous Diffusion Plant Federal Facility Agreement Semiannual Progress Report for the First Half of Fiscal Year 2017 Paducah, Kentucky,* DOE/LX/07-2416/V1, U.S. Department of Energy, Paducah, KY, April.

FPDP 2016. *Environmental Monitoring Plan, Fiscal Year 2016, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, CP2-ES-0006, Fluor Federal Services, Inc., Paducah, KY, January.

FPDP 2017a. *Environmental Monitoring Plan, Fiscal Year 2017, Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, CP2-ES-0006/R1, Fluor Federal Services, Inc., Paducah, KY, January.

FPDP 2017c. *National Emissions Standards for Hazardous Air Pollutants Annual Report for 2016*

U.S. Department of Energy Emissions at the Paducah Gaseous Diffusion Plant, FPDP-RPT-0089, Fluor Federal Services, Inc., Paducah, KY, June.

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

Fraction and multiples of the Curie

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 calcium carbonate dissolved in water, usually expressed as part of calcium carbonate per million parts of 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.

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.

APPENDIX A - MCHS ASER STUDY GUIDE Q & A

0. SITE HISTORY AND BACKGROUND

1. Intro Information: (http://www.paducahvision.org/paducahvm/index.html)

2. Why did the Federal Government need to develop processes to obtain nuclear material prior to and during World War II? (http://www.paducahvision.org/paducahvm/index.html 'The Need for Uranium')

3. Following World War II, the Soviet Union completed development of and detonated its first atomic weapon in what year? _________ (http://www.paducahvision.org/paducahvm/index.html 'The Need for Uranium')

4. The Korean War began in what year? _________ (http://www.paducahvision.org/paducahvm/index.html 'The Need for Uranium')

5. The Korean War involved what nations? North ______ supported by ________, South _____ supported by the ________ ______ and United Nations and China. (http://www.paducahvision.org/paducahvm/index.html 'The Need for Uranium')

6. Following the start of the Korean War the U.S. had accumulated sufficient nuclear material to produce atomic weapons and expand the 7True or False? (http://www.paducahvision.org/paducahvm/index.html 'The Need for Uranium')

7. In order to produce nuclear material in quantities needed to make weapons, the Federal Government decided to build the _________ _________ ________ _______ (PGDP) in McCracken County, Kentucky. (http://www.paducahvision.org/paducahvm/index.html 'The Need for Uranium')

8. The PGDP is located in ________ County approximately 13 miles west of the city of Paducah. (http://pgdpvirtualmuseum.org/began.html 'PGDP & Vicinity Maps')

9. The PGDP occupies approximately 1 square mile of a Department of Energy (DOE) Reservation. True or False? (http://pgdpvirtualmuseum.org/began.html 'PGDP & Vicinity Maps')

10. In what year did the construction of the PGDP begin? (http://pgdpvirtualmuseum.org/life-at-the-plant.html 'Timeline: History of PGDP – Construction and Operations')

11. Enrichment is the process of increasing the amount of the uranium-235 isotope in uranium compared to the amount of uranium-235 in naturally-occurring uranium. True or False? (http://pgdpvirtualmuseum.org/whatis.html)

12. The PGDP used the process of ________ ________ which required uranium to be mixed with fluorine to produce gaseous uranium hexafluoride (UF6). (http://www.ukrcee.org/ 'Paducah Gaseous Diffusion Plant: A Challenge in Progress')

13. Gaseous uranium hexafluoride (UF6) was passed thru membranes that contained holes less than 1/1 millionth of an inch in diameter which allowed the separation of atoms of uranium-235 from atoms of uranium-238. True or False? (http://pgdpvirtualmuseum.org/whatis.html 'What is Enrichment' and 'The Gaseous Diffusion Process')

14. The PGDP started enriching uranium in __________. (http://pgdpvirtualmuseum.org/life-at-the-plant.html 'Timeline: History of PGDP – Construction and Operations')

15. The PGDP stopped enriching uranium in __________. (http://pgdpvirtualmuseum.org/life-at-the-plant.html 'Timeline: History of PGDP – Construction and Operations')

16. The primary mission of the PGDP was ________ uranium for use in atomic weapons and for use as fuel to power the nuclear navy and nuclear power plants that produce electricity. (http://pgdpvirtualmuseum.org/missions.html)

17. PGDP Missions developed as the Site enriched uranium and later ceased enrichment of uranium and included 6 major activities: (http://pgdpvirtualmuseum.org/missions.html)
Uranium Enrichment

____

____

____

____

____

18. Other missions of the PGDP developed as the Site enriched and later ceased enrichment of uranium. Those activities are broadly referred to as "Deactivation, Decontamination, and Decommissioning". Deactivation is the removal of radioactive and hazardous materials from _________, ________, and ___________. (http://pgdpvirtualmuseum.org/decommissioning.html)

19. The C-340 Metals Plant produced uranium metal that was milled, packaged and shipped to customers. (True or False)?

20. The first Federal environmental regulation, the _______ _______ _______ _______ Act became law in 1948. (http://pgdpvirtualmuseum.org/remediation.html Focused Timeline: History of PGDP Environmental Accomplishments and the Evolution of Environmental Regulations).

21. The solvent trichloroethene (TCE) was used to clean process components prior to installation at the PGDP. PGDP TCE use began in ____. (http://pgdpvirtualmuseum.org/remediation.html Focused Timeline: History of PGDP Environmental Accomplishments and the Evolution of Environmental Regulations).

22. The United States Environmental Protection Agency (EPA) was formed in _________. (http://pgdpvirtualmuseum.org/remediation.html Focused Timeline: History of PGDP Environmental Accomplishments and the Evolution of Environmental Regulations).

23. The Resource Conservation and Recovery Act (RCRA) became law in 1976 and regulates the management and disposal of solid and hazardous waste from _________ to ________. (http://pgdpvirtualmuseum.org/remediation.html Focused Timeline: History of PGDP Environmental Accomplishments and the Evolution of Environmental Regulations).

24. Groundwater Pump and Treat operations at PGDP were implemented to remove _________ groundwater at the PGDP. More than 4 ______ gallons of contaminated groundwater have been extracted and treated at the PGDP. (http://pgdpvirtualmuseum.org/remediation.html 'Environmental Remediation')

1. INTRODUCTION

1.0 Purpose of the Document (From Executive Summary)

What drives the environmental actions and monitoring at the PGDP?

What are the major environmental monitoring activities?

What are the goals of the Environmental Management Program?

What companies managed the PGDP work in 2016?

1.1. THE PGDP SITE

1.1.1. The area surrounding the PGDP is generally _____. (Page 1-1. 'Site Location' and Figure 1.1. Location of the Paducah Site)

1.1.2. Why was the location in McCracken County chosen? __________

1.1.3. The Paducah Gaseous Diffusion Plant (PGDP) industrial site occupies approximately one square mile of a 3,556 acre Department of Energy (DOE) Reservation. True or False?

1.1.4. Surrounding Land Ownership includes the West Kentucky Wildlife Management Area (WKWMA) which is operated by the Commonwealth of Kentucky, Department of Natural Resources. (True or False?)

1.1.5. What industrial facility occupied the area of the PGDP during WWII? __________

1.1.5.1. What did the facility produce? ____________

1.2. GENERAL ENVIRONMENTAL SETTING

1.2.1. Climate (Describe)

1.2.2. Surface Water Drainage

1.2.2.1. The PGDP is located on a divide between the watersheds of _____ and _____ _______ Creeks which discharge into the Ohio River (Figure).

1.2.3. Wetlands

1.2.3.1. Describe local wetlands (Figure)

http://paducaheic.com/Search.aspx?accession=I-04502-0003

1.2.3.2. Cite the wetlands document that MCHS 2014 and 2015 helped to develop

1.2.4. Soils and Hydrogeology

1.2.4.1. Describe the local soil types

1.2.4.2. Describe local Hydrogeology (groundwater flow system) and reference more information in this doc.

1.2.4.3. Vegetation

1.2.4.3.1. Has vegetation been impacted by human activity? Yes or No?

1.2.4.3.2. Describe vegetation types found DOE Reservation and surrounding areas

1.2.5. Habitats

1.2.5.1. What habitats are found on the DOE Reservation and surrounding areas?

1.2.6. Wildlife

1.2.6.1. What wildlife habitats are found at PGDP, DOE Reservation and WKWMA?

1.2.6.2. What species are present?

1.2.7. Threatened and Endangered Species

1.2.7.1. What threatened and endangered species potentially might exist in habitats ID'ed at the PGDP, WKWMA and surroundings?

1.2.7.2. Have any of the federally listed threatened or endangered species been identified to inhabit the area?

1.3. SITE MISSION

1.3.1. The DOE's primary mission at the PGDP was ______________________________. (mission = focus of activities)

1.3.2. What DOE organization was formed to manage DOE's responsibilities at the PGDP?

1.4. PRIMARY OPERATIONS AND ACTIVITIES AT THE PADUCAH SITE

1.4.1. The two major programs DOE operates at the PGDP are the _________ and _________.

1.4.2. Other missions include: ____________, _______________, _________________, ____________________, _____________. (Chapter 0 Text and Questions)

1.4.3. What missions are currently being addressed \and will continue at site in the future? (Chapter 0 Text and Questions)

2. REGULATION and COMPLIANCE SUMMARY

When did the Federal Government begin to pass and implement environmental regulations and why? (Timeline).

What are the two prominent regulatory agencies that have authority for environmental work at the PGDP?

What are the two main environmental/hazardous waste regulation programs that DOE must comply with at the PGDP?

What is the responsibility of each agency and how is regulatory authority between the two agencies handled?

What federal government agency is responsible for radiation protection at the PGDP?

What State of Kentucky Agency is responsible for off-site radiation protection at the PGDP?

2.1 ENVIRONMENTAL RESTORATION AND WASTE MANAGEMENT

2.1.1. Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

What is CERCLA? (Page 2-1)

What is regulated under CERCLA? See https://www.epa.gov/superfund/superfund-cercla-overview

Under CERCLA what list is a site placed on when it needs the highest priority for remediation?

When a site is on the National Priorities List (NPL), the site must enter what agreement with the Environmental Protection Agency to establish a decision making process for site remediation?

2.1.2. Superfund Amendments and Reauthorization Act (SARA)

What is SARA? See https://www.epa.gov/superfund/superfund-amendments-and-reauthorization-act-sara (Page 2-1).

2.1.3. Resource Conservation and Recovery Act

What is the Resource Conservation and Recovery Act? (Page 2-2)

What is regulated under RCRA? See https://www.epa.gov/rcra

RCRA establishes regulatory standards for the ________________, __________________, _____________, and ________________ of solid and hazardous waste.

What is hazardous waste? See https://www.epa.gov/hw

What is mixed waste? Mixed waste contains _______________ and _____________ components.
See https://search.epa.gov/epasearch/epasearch?querytext=mixed+waste&areaname=&areacontacts=&areasearchurl=&typeofsearch=epa&result_template=2col.ftl

2.1.4. Resource Conservation and Recovery Act Hazardous Waste Permit

Who issues the hazardous waste permit for the PGDP?

2.1.5. Federal Facility Compliance Act (FFCA) – Site Treatment Plan (STP)

What did the FFCA do to change the responsibility of Federal Facilities relative to RCRA?

See https://www.epa.gov/enforcement/resource-conservation-and-recovery-act-rcra-and-federal-facilities

Under the FFCA, efforts to minimize waste and pollution are based on what 5 goals? (Page 2-3)

2.1.6. National Environmental Policy Act (NEPA)

Under NEPA, a site must evaluate the ______________ ______________ of certain Federal activities related to the environment. (Page 2-3)

What actions taken by the site require a NEPA review?

2.1.7. Toxic Substances Control Act (TSCA)

What are the two purposes of TSCA? (Page 2-4)

What chemical specific Act applies to the following two chemicals/mixtures used in the construction and operation of the PGDP: 1) Asbestos that was used at PGDP to insulate buildings and equipment and 2) polychlorinated biphenyls (PCBs) were widely used as a component of electrical equipment.

What is the name of an update to TSCA that specifically applies to the PGDP and its historical role enriching uranium?

2.2. RADIATION PROTECTION

What Federal Act gives DOE regulatory authority over the atomic (radioactive) material it handles? (Page 2-5)

DOE implements DOE ______ that establish requirements for 1) protection of the public and environment from radiation as well as 2) the management of radioactive wastes associated with its activities?

DOE Order ________ is implemented to provide radiation protection of the public and environment.

DOE Order ________

Authorized _______ for radiation have been developed for the PGDP's C-746-U Landfill and DOE property outside of the industrial (limited) area.

Additional _________ __________ are in place for lube and transfer oils that will be destroyed thermally, other materials that will be released for re-use, and materials that will be shipped to off-site disposal facilities.

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

An Environmental Radiation Protection Program (ERPP) was implemented at the PGDP by _______ ________ ________ ___________, the primary contractor in charge of site environmental and decommissioning for the Department of Energy (DOE).

The goals of the ERPP are:

1) ____.

2) ____.
3) ____.
4) ____.
5) ____.

2.2.2. DOE Order 435.1, Radioactive Waste Management

Radioactive waste is waste that contains ___________________ material. (Radiation 101 Presentation)

The PGDP manages three types of radioactive waste under procedures established by DOE Order 435.1: (Page 2-6)

1) ____.
2) ____.
3) ____.

2.3. AIR QUALITY AND PROTECTION

2.3.1. Clean Air Act

The Clean Air Act was established in _____________________.
(http://pgdpvirtualmuseum.org/remediation.html **'Focused Timeline: History of PGDP Environmental Accomplishments and the Evolution of Environmental Regulations'**)

Enforcing compliance with the Clean Air Act and its amendments is the responsibility of what Federal and State Agencies? (Page 2-6)

Radioactive and hazardous materials that could impact air quality at the PGDP are monitored at ________ points.

2.3.2. National Emission Standards for Hazardous Air Pollutants Program (NESHAPS)

Airborne emission of radionuclides at DOE facilities is regulated under what regulation? (Page 2-7)

What are the potential sources (activities) at PGDP that require management of air releases of radionuclides?

Local background air quality data is collected at nine __________ air monitoring stations surrounding the PGDP.

Air monitors surrounding the PGDP are _______ powered.

2.3.3. Pollutants and Sources Subject to Regulation

The process of dismantling the industrial enrichment process equipment, the buildings, and support facilities that house the equipment is referred to as the ___________ Project which is a source of pollutants subject to regulation. (Page 2-7)

Spent uranium hexafluoride from the enrichment process is referred to as 'depleted' uranium hexafluoride (DUF6) because some portion of uranium-235 has been removed compared to the amount of uranium-235 in _________ occurring uranium.

The process of reclaiming uranium and fluorine from uranium hexafluoride that will no longer be enriched is referred to as ____________.

The conversion process is considered a potential source of _____ pollution and is permitted by the Kentucky

Division of Air Quality (KDAQ).

Uranium is prepared for disposal in a stable form that does not interact with the environment and hydrogen fluoride is re-used by industry. True or False?

2.3.4. Stratospheric Ozone Protection

Approximately 6.3 _____ pounds of R-114 refrigerant, a potential ozone depleting substance if released, were utilized in a PGDP cooling system. (Page 2-8)

Releases of the R-114 refrigerant and sources of releases are tracked under permit and __ ___ Part ___ requirements.

2.4. WATER QUALITY AND PROTECTION

2.4.1. Clean Water Act

The Federal Water Pollution Control Act Amendments of 1972 established four major programs for control of water pollution: (Page 2-8)

1) ____.
2) ____.
3) ____.
4) ____.

2.4.2 Kentucky Pollutant Discharge Elimination System (KPDES)

The Clean Water Act applies to DOE discharges to waters of the United States that do not contain radiation components and PGDP effluent discharges to Bayou and Little Bayou Creek are regulated under the ______ ________ _____ ______ _____ (_ _ _ _ _) permit system. (Page 2-8)

KPDES permits require the implementation of a _____ __________ ________ Plan to prevent or minimizes the potential for release of pollutants. (Page 2-9)

Outfalls are locations where PGDP releases water from the industrial site and support facilities to Bayou and Little Bayou Creeks. There are approximately __ outfalls permitted at the PGDP.

During 2016 there were __ exceedances of permit criteria at the PGDP. (Page 2-9, Table 2.2)

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

2.4.4 Safe Drinking Water Act (SDWA)

The PGDP obtains water from the ____ _____ and treats it for use (drinking and industrial) in an on-site water treatment plant. (Page 2-9)

The PGDP is permitted to withdraw ____ million gallons per day (mgd) of water from the Ohio River.

The ____ ____ ____ Act sets limits for contaminants in treated water that is distributed through the sanitary water distribution systems.

2.5 OTHER ENVIRONMENTAL STATUTES

2.5.1 Endangered Species Act

The Endangered Species Act designates and protects endangered ______ and _______. (Page 2-10)

The Endangered Species Act also protects the _________ where endangered plants and animals are likely to occur.

How many endangered mammal, clam, and bird species potentially occur in the vicinity of the PGDP? (Page 2-10, Table 2.3)

2.5.2 National Historic Preservation Act

The National Historic Preservation Act is the law that sets the criteria for the identification and preservation of historical and archeological sites. At the PGDP there have been _______ properties/locations identified as eligible for the National Register of Historic Places. (Page 2-11)

The limited or _________ area of the DOE reservation encompasses the PGDP historic district.

2.5.3 Migratory Bird Treaty Act

The DOE and the __. __. _____ _ _______ Agency have a formal agreement, or Memorandum of Understanding, that outlines actions to be taken at the PGDP to protect migratory birds. (Page 2-11)

2.5.4 Asbestos Program

Asbestos was used as an ___________ material in many facilities at the PGDP. (Page 2-11)

2.5.5 Floodplain/Wetlands Environmental Review Requirements

Two Federal Regulations, 1) __________, 2) __________ and Executive Order _________ require the PGDP to comply with management and protection of floodplains and wetlands. (Page 2-11)

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

Underground storage tanks are regulated under the ________ _______ & ______ Act. (Page 2-11)

2.5.7 Solid Waste Management

Paducah disposes of some of its solid waste on-site in the C-____-U Landfill, a facility permitted by the Kentucky Division of Waste Management. (Page 2-12)

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

2.6.1 Departmental Sustainability

DOE Order ____, _______ ________ commits the DOE to pursue the U.S. Green Building Council Leadership in Energy and Environmental Design. (Page 2-12)

2.6.2 Federal Leadership in Environmental, Energy, and Economic Performance

Executive Order 13693, enacted in 2011, requires Federal agencies to establish goals to reduce _______ gases. (Page 2-12)

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

Under EPCRA, the PGDP is required to report to the public emergency planning information, _________ ________ inventories and __________ to the environment. (Page 2-12)

Releases to the environment include _________________ gases. (Page 2-13)

2.8 OTHER MAJOR ENVIRONMENTAL ISSUES AND ACTIONS

2.8.1 Green and Sustainable Remediation

Green and sustainable remediation may offer opportunities to reduce __________ and ________ impacts of remedial cleanup. (Page 2-13)

2.8.2 Adapting to Climate Change

The majority of greenhouse gases emitted at the PGDP are related to what activities? (Page 2-13)

2.9 CONTINUOUS RELEASE REPORTING

The PGDP had ___ continuous releases of hazardous substances during 2016. (Page 2-14)

2.10 UNPLANNED RELEASES

Storm water containing _______ was released through KPDES 011 in 2016 and a courtesy reporting detailing the incident was provided to the KDWM. (Page 2-14)

2.11 SUMMARY OF PERMITS

EPA issued _______ permit to the DOE and its site contractor FFS during 2016. (Page 2-14, Table 2.5)

KDWM (Kentucky Division of Waste Management) issued ________ permits to the DOE and its contractors during 2016.

The Kentucky Division of Air Quality (KDAQ) issued _________ permits to PGDP site contractors during 2016.

Permits issued to the DOE and its PGDP contractors during 2016 under three (3) Acts administered:

1) ____.
2) ____.
3) ____.

3. REGULATION and COMPLIANCE SUMMARY

The Environmental Management System (EMS) integrates __________________, __________________, _______________, _______________ & _________________.

What organizations are required to implement the EMS at the PGDP?

3.1 ENVIRONMENTAL OPERATING EXPERIENCE AND PERFORMANCE MEASUREMENT

The Environmental Monitoring Program (EMP) at the PGDP has the following components: ______________, _______________ & _________________.

During 2016 the DOE, through site contractor FPDP, documented the EMP in the document titled _________________.

3.1.1 Site Sustainability Plan

What is environmental stewardship? https://en.wikipedia.org/wiki/Environmental_stewardship

What is the definition of sustainability? https://www.epa.gov/sustainability/learn-about-sustainability#what

DOE manages sustainability at the PGDP relative to DOE Order ____________ and Executive Order ____________.

DOE's PGDP Site Sustainability Plan outlines ten (10) major categories of activities that are managed for sustainability. The ten categories are:

1. _________________________
2. _________________________
3. _________________________
4. _________________________
5. _________________________
6. _________________________
7. _________________________
8. _________________________
9. _________________________
10. _________________________

3.1.2 Waste Minimization/Pollution Prevention

The PGDP Waste Minimization/Pollution Prevention Program provides guidance for __________________.

The PGDP Waste Minimization/Pollution Prevention Program applies to __________ Site activities that generate or have the potential to generate waste.

List four (4) goals of the PGDP Waste Minimization/Pollution Prevention Program.

1. _________________________
2. _________________________
3. _________________________
4. _________________________

In CY 2016 PGDP reported five (5) waste minimization and pollution prevention accomplishments. What were the accomplishments?

1. ___________________________
2. ___________________________
3. ___________________________
4. ___________________________
5. ___________________________

3.1.3 Depleted Uranium Hexafluoride Cylinder Program

What is DUF6?

How is DUF6 stored at the PGDP?

The purpose of the Depleted Uranium Hexafluoride Cylinder Program is?

3.1.4 Environmental Restoration, Waste Disposition, and Deactivation and Decommissioning

What is Deactivation and Decommissioning (D&D)?

Environmental investigations, environmental response actions, D&D (deactivation and decommissioning) of unused facilities and other programs for the protection of human health and the environment are part of the PGDP ____________ ______________ ______________.

List two (2) of the seven (7) reported PGDP environmental restoration, D&D and waste disposition activities accomplished during 2016.

1. ___________________________
2. ___________________________

3.1.5 Emergency Management

The PGDP has its own security force, _____________________, and _____________.

The general public is informed of emergency situations through the PGDP ___________ __________ __________ Center.

3.1.6 Facility Stabilization, Deactivation, and Infrastructure Optimization

3.2 ACCOMPLISHMENTS, AWARDS, AND RECOGNITION

DOE interacts with the public and provides information to the public through the Paducah _______________ __________________ Board, the DOE Environmental Information Center, and educational outreach programs.

3.2.1 Public Awareness Program

DOE interacts with the public through a comprehensive PGDP __________ __________ and ________ _________ Program which supports public involvement with Site environmental decision making.

3.2.2 Community/Educational Outreach

DOE and its contractors engaged local Kentucky High School students with two (2) activities:

1. ___________________________
2. ___________________________

MCHS students participate in an educational outreach program about environmental issues at the PGDP through a program centered on the review of the PGDP ____________ ___________ __________ ________.

As part of the MCHS ASER Program 2018 students were provided access to the PGDP __________ ___________ which contains extensive history and documentation of the DOE's activities at the PGDP.

Interactive maps showing environmental monitoring locations and data for the PGDP can be accessed through the _____________, the Paducah Environmental Geographic Analytical Spatial Information System developed by the UK Kentucky Research Consortium for Energy and Environment and operated by DOE site contractors. https://pegasis.ffspaducah.com/what-is-pegasis.html

3.2.3 Citizens Advisory Board

The _________ __________ _________ (CAB) is composed of members representing business, academia, labor, local government, environmentalists, special interest groups, and the general public from western Kentucky and surrounding areas.

3.2.4 Environmental Information Center

Documents produced for environmental activities and projects at the PGDP can be accessed at the PGDP ____________ _____________ _____________. http://www.paducaheic.com/

4. ENVIRONMENTAL RADIOLOGICAL PROTECTION PROGRAM AND DOSE ASSESSMENT

4.1 ENVIRONMENTAL RADIOLOGICAL MONITORING PROGRAM

What is radioactive decay? http://www.paducahvision.org/paducahvm/whatis.html

Ionizing radiation is? https://en.wikipedia.org/wiki/Ionizing_radiation

Material that contains atoms that undergo radioactive decay is referred to as ________ material.

A radionuclide is an atom of an element or element's isotope(s) that exhibits _________ decay.

Radioactive decay is a ________ reaction.

When radioactive decay occurs it results in the formation of a new _______ of the parent element or lighter elements.

Radioactive decay is capable of releasing vast amounts of _________.

The isotope of an element is "fissile" when it is capable of a self-sustained, or chain, nuclear reaction. True or False

At PGDP, an industrial process was used to increase the amount of the _________ isotope in uranium compared to the amount in naturally occurring uranium.

U-235 was a desirable material because it a ________ isotope of uranium capable of sustaining and chain nuclear reaction that releases energy.

Routine DOE operations at the Paducah Site may result in releases of radioactive materials to the environment by _________ and __________ pathways.

A __________ ________ occurs when an individual or organism is exposed to radioactive material.

What are two sources of radiation exposure that we all experience?

1. _________________________
2. _________________________

When a person or organism is exposed to radioactive material, the amount of exposure is measured as _____ (a four letter word).

Dose is the amount of ________ absorbed by the body as a result of exposure to _________ ________.

DOE monitors radiation exposure through DOE Order ______, *Radiation Protection of the Public and the Environment*.

DOE Order 458.1 limits radiation dose to the public to 100 _______ per year.

4.1.1 What Is Dose?

When a person or organism is exposed to radioactive material, the amount of exposure is measured as _____ (a four letter word).

An _______ exposure occurs when a person receives a dose from a radioactive material source outside of the body.

An ________ exposure occurs when a person receives a dose from a radioactive material source that has been ingested or is inside of the body.

Routine exposure to ionizing radiation results in an annual effective dose to individuals of _____ mrem/yr.

Naturally occurring cosmic and terrestrial sources of ionizing radiation result in an average dose to individuals of ____ mrem/yr.

4.1.2 Radioactive Materials at the Paducah Site

The PGDP processed uranium to increase the amount of uranium's ________ isotope relative to the amount of U-235 in naturally occurring uranium.

U-235 is a ________ radionuclide (meaning it is capable of a sustained nuclear reaction resulting in a continuous release of energy)

Radioactive materials present at the Paducah Site are the result of processing raw and recycled uranium. True or False?

The half-life of a radionuclide is? https://www.britannica.com/science/half-life-radioactivity

Radionuclides processed at the PGDP include:

1. ___________________________
2. ___________________________
3. ___________________________

Other Radionuclides that may be present at the PGDP include:

1. ___________________________
2. ___________________________
3. ___________________________
4. ___________________________
5. ___________________________
6. ___________________________
7. ___________________________

When a parent radioactive material undergoes decay, the new isotopes of the radionuclide that are formed are referred to as ________ products.

4.1.3 What is an Exposure Pathway?

An exposure pathway is how a radioactive material is __________to the environment, __________ to a receptor (person, animal, or plant), and comes into contact with a receptor.

Five potential radioactive material exposure routes are identified in the ASER:

1. ___________________________
2. ___________________________
3. ___________________________
4. ___________________________
5. ___________________________

4.1.4 Dose Assessment Methodology

Specific methods for assessing dose at the PGDP are required under DOE Order 458.1 and identified in the document *Methods for Conducting Risk Assessments and Risk Evaluations (at the PGDP).* True or False?

4.1.5 Air Monitoring and Estimated Dose from Airborne Effluents

DOE remedial actions and other activities could possibly release radionuclides into the atmosphere. Airborne releases may result from _______ or ______ sources (any two of 5 listed sources).

4.1.6 Liquid Discharge Monitoring and Estimated Dose from Liquid Effluents

4.1.6.1 Surface water

Radioactive materials released to surface water as radioactive contaminants may leave the PGDP and be deposited in ____________, deposited on ground or vegetation by __________, taken up by plants, ingested by animals, or may infiltrate to ___________.

DOE Order 458.1 requires the ____________________ and control of radionuclides in surface water releases from the PGDP.

Water released through PGDP ditches and industrial activities to off-site surface waterways is known as effluent. True or False?

Environmental monitoring of surface water for radionuclides is conducted at ____ locations including background locations or locations upstream of PGDP impacts. (Figure 4.4)

Effluent surface water leaves the PGDP site at 15 locations known as ___________. (Figure 4.4)

4.1.6.2 Drinking water

Surface water from the PGDP is used as a drinking water source. True or False?

Surface water from the PGDP discharges to _________ Creek and ________ _________ Creek which discharge to the Ohio River.

Cairo, Illinois utilizes the Ohio River as a drinking water source. Because Cairo, Illinois is downstream of the confluence of Bayou and Little Bayou Creeks with the Ohio River the withdrawal point for drinking water is monitored for radionuclides. True or False?

4.1.6.3 Incidental ingestion of surface water

DOE calculates the dose that could be accidentally or incidentally received from a person swimming in Bayou or Little Bayou Creeks. True or False?

4.1.6.4 Landfill leachate

Radionuclides in landfill leachate are monitored under DOE Order 458.1 and are not monitored under the landfill operating permit. True or False?

4.1.6.5 Groundwater

Groundwater downgradient (downstream) of the PGDP site is not considered in dose calculations because it is not utilized as a drinking water source. True or False?

The DOE provides water to residents downgradient of the PGDP under its Water Policy which began when groundwater contamination was found in drinking water wells. True or False?

4.1.7 Sediment Monitoring and Estimated Dose

Sediment is a portion of the aquatic ecosystem? True or False.

Sediments can act as a repository of contaminants released from source areas? True or False?

4.1.7.1 Sediment surveillance program

Approximately ___ locations (including background locations) are monitored for accumulations of undissolved radionuclides in sediment. (Figure 4.5)

4.1.7.2 Sediment dose

Incidental _________ is the pathway evaluated for sediment dose to an individual.

The highest annual dose to a potentially exposed individual from sediment ingestion was ______ mrem/yr at station ____ in Bayou Creek.

Sediment sampling station S1 is a background location. True or False?

4.1.8 Terrestrial Environment Monitoring and Estimated Dose

Terrestrial dose could potentially occur from PGDP activities and include the following pathways:

1. ___________________________
2. ___________________________
3. ___________________________

Irrigation of crops in areas potentially impacted by PGDP activities utilizes municipal water instead of utilizing local groundwater. True or False?

4.1.9 Wildlife

Raccoons and deer in the vicinity of the PGDP have been evaluated (historically) for uptake of radionuclides. True or False?

In general, ____________ were not routinely detected in tissue from deer harvested in the vicinity of the PGDP. True or False?

4.1.10 Direct Radiation Monitoring and Estimated Dose

4.1.10.1 Direct radiation surveillance

The public is potentially impacted by external radiation from the PGDP. True or False?

Radioactive sources outside the body are responsible for ___________ radiation exposure.

Three (3) potential sources of external radiation at the PGDP include:

1. ___________________________
2. ___________________________
3. ___________________________

Thermoluminescent dosimeters, or ___________ are used to monitor direct radiation exposure on individuals and in locations where individuals might be exposed to external radiation sources.

4.1.10.2 Direct radiation dose

In areas accessible to the public the estimated external radiation dose to an individual was _______ mrem/yr.

The maximum allowable radiation dose to an individual under DOE Order 458.1 is ________ mrem/yr.

At ________ locations, dosimeters indicated that external radiation dose to an individual slightly exceeded background levels? (Figure 4.6)

4.1.10.3 Cumulative dose calculation

Cumulative dose represents the calculated dose of individuals from both atmospheric and liquid releases. True or False?

The cumulative dose to a hypothetical most exposed individual from PGDP activities was _______ mrem/yr.

4.1.11 Biota Monitoring and Estimated Dose

4.1.11.1 Biota surveillance

Radionuclides and other contaminants can ___________________ in fish if they consume contaminated food sources or ingest contaminated materials in the aquatic environment.

4.1.11.2 Biota dose

Dose is evaluated for aquatic and terrestrial biota utilizing methods in a DOE guidance document. True or False?

4.2 CLEARANCE OF PROPERTY CONTAINING RESIDUAL RADIOACTIVE MATERIAL

DOE and its contractors must use limits material radioactivity limits identified in DOE Order 458.1 before releasing potentially impacted items or materials for re-use, re-cycling or disposal. True or False?

4.3 UNPLANNED RADIOLOGICAL RELEASES

There were ____ unplanned releases of radionuclides at the PGDP during 2016.

5. ENVIRONMENTAL NONRADIOLOGICAL PROGRAM INFORMATION

5.1 AIR MONITORING

No active non-radiological air monitoring was required at the PGDP during 2016. True or False?

5.2 SURFACE WATER MONITORING

The ______ _______ ___ applies to discharge of PGDP's surface water to surface water of the _________.

The Kentucky Division of _______ (KDOW or KDW) administers surface water regulations in the State of Kentucky.

Discharge of site runoff and industrial-process effluents requires permits and monitoring. True or False.

The Kentucky Division of Waste Management (________) issues permits for the operation of landfills in the State.

KDWM landfill operating permits require surface water monitoring for ___-____________constituents from landfills. (Section 2.4.2)

There are __ KPDES-permitted Outfalls at the PGDP where surface water leaves the PGDP and comingles with the surface waters of Kentucky. (Figure 4.4.)

During 2016 there were _ exceedances of non-radiological constituents at PGDP surface water monitoring locations. (Table 2.2)

Table 5.1 summarizes the monitoring and reporting for non-radiological _______ _______ monitoring locations at the PGDP.

___ analytes were detected in PGDP-monitored surface water during 2016. (Table 5.2)

Identify the potential source(s) for one of the analytes listed in Table 5.2 and what impact an excessive amount of the analyte in surface water could have.

5.3 SEDIMENT MONITORING

Polychlorinated biphenyls (PCBs) were used extensively at the PGDP because of their electrical and cooling properties. True or False?

PCBs were detected as contaminants in routine PGDP sediment monitoring during 2016. True or False?

Many of the sediment sample PCB results exceeded levels requiring a response action as defined by Action and No Action Levels in the PGDP *Methods for Conducting Risk Assessments and Risk Evaluations* guidance document. True or False?

5.4 BIOTA MONITORING

Biological Monitoring was required for surface water at the PGDP in 2016. True or False?

5.4.1 Aquatic Life

What is chronic and acute toxicity monitoring?
https://www3.epa.gov/region1/npdes/permits/generic/freshwaterchronictoxtest-rev.pdf

Warning signs are posted along Bayou and Little Bayou Creeks to warn members of the public about the _______ 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 on the DOE reservation follows Federal interagency guidance *Wildland Fire Management Plan*, CP2-EP-1005. True or False?
https://www.frames.gov/files/8514/9797/5268/fedwildlandpolicy.pdf

5.6 RECREATIONAL HUNTING AND FISHING

Hunting and fishing is allowed by permit on DOE-owned lands that are leased by the Kentucky Department of Fish and Wildlife (KDFW) West Kentucky Wildlife Management Area. True or False?

6. GROUNDWATER PROTECTION PROGRAM

The Regional Gravel Aquifer is the primary aquifer for local groundwater users in the vicinity of the PGDP. True or False?

There are two primary off-site contaminants that impact Regional Gravel Aquifer (RGA) groundwater which are an industrial degreaser ___________ and the radionuclide technetium-99.

Trichloroethylene (TCE) was used until 1993 as an industrial degreasing solvent to clean enrichment process equipment and hundreds of miles of enrichment process piping. True or False?

Nuclear fission is the process that releases energy from fuel rods in nuclear reactors that produce electricity. True or False? (VM: Nuclear Energy and the Atom)

Technetium-99 is a fission by-product contained in nuclear power reactor returns (spent nuclear fuel rod material) processed at the PGDP for re-enrichment of their uranium-235 content. True or False?

Two large groundwater plumes containing TCE and technetium-99 originate at the PGDP and occur in the RGA. They are the referred to as the __________ and ________ groundwater plumes.

Cumulatively, the Northeast and Northwest Groundwater Plumes are amongst the largest areas of groundwater contamination in the U.S. and the World that originate from a single facility. True or False?

One of the two large groundwater plumes comprises the largest TCE/technetium-99 in the DOE Complex (all DOE facilities nationwide). True or False.

Re-enrichment of uranium-235 from spent nuclear fuel containing technetium-99 ended in Calendar Year _______.

Known or potential sources of TCE and technetium-99 include:

1. _________________________
2. _________________________
3. _________________________
4. _________________________
5. _________________________
6. _________________________

Groundwater locations monitored during 2016 are identified in Figure ______.

Groundwater monitoring is conducted to detect the _______ and _______ of groundwater contamination

The nature of groundwater contamination is defined by the detection of ________________ and their concentrations at given locations in the Regional Gravel Aquifer.

Groundwater monitoring is utilized to determine the movement of groundwater (rate and direction) in the vicinity of the PGDP. True or False?

Historical groundwater data and interactive maps showing groundwater monitoring locations can be viewed and downloaded from the PEGASIS (Paducah Environmental Geographic Analytical Spatial Information System; https://pegasis.ffspaducah.com/). True or False?

6.1 GEOLOGIC AND HYDROGEOLOGIC SETTING

There are several groundwater components to the groundwater flow system at the PGDP:

1. ___________________________
2. ___________________________
3. ___________________________
4. ___________________________

Groundwater flow through loess and shallow soils, the Upper Continental Recharge System is primarily _______________ and provides recharge to the RGA.

Regional Gravel Aquifer groundwater flows ______ toward the Ohio River and discharges to the Ohio River and _________ in the vicinity of the Ohio River.

Most contaminant sources at the PGDP are in the RGA. True or False?

The primary area of recharge for the McNairy Flow System, which occurs beneath the RGA, is along the western side of Kentucky Lake and includes ________ and Graves Counties.

6.2 USES OF GROUNDWATER IN THE VICINITY

Historically, _____________________ was the primary source of agricultural irrigation water and residential drinking water in the vicinity of the PGDP.

Contamination of groundwater by contaminants related to the PGDP was first identified by the Kentucky Radiation Control Program and the McCracken County Public Health Department in 1988. True or False?

When off-site groundwater contamination associated with PGDP was identified, the DOE provided access to and paid for municipal water for individuals, farms and businesses in areas potentially impacted by PGDP groundwater contamination. True or False?

The DOE provides water to potentially impacted individuals through the DOE _______ ________ Program.

6.3 GROUNDWATER MONITORING PROGRAM

The primary objective of the PGDP groundwater monitoring program is to ensure protection of public health and the environment.

Five additional objectives of the DOE groundwater monitoring program are:

1. ___________________________
2. ___________________________
3. ___________________________
4. ___________________________
5. ___________________________

Table ___ summarizes PGDP groundwater monitoring, groundwater flow system components that are monitored, and the frequency of monitoring.

6.4 GROUNDWATER MONITORING RESULTS

Table __ summarizes the analytes that were detected in PGDP groundwater samples during 2016.

The maximum contaminant level for TCE in groundwater is _____ ug/L.

The maximum extent of TCE groundwater contamination shown in Figure 6.1 is _____ ug/L.

The maximum concentration of TCE in groundwater during 2016 was ______ ug/L.

In 2016, the maximum TCE groundwater concentration was found in samples collected in the vicinity of the C-400 _______ ________.

TCE was delivered by railroad tank cars, transferred, stored and used to clean enrichment process components at the C-400 Cleaning Building.

During the cleaning process in the C-400 Building, TCE vapors were withdrawn from cleaning processes and discharged to the atmosphere thru stacks on the east side of the building. True or False?

Cleaning water used to rinse and remove TCE during cleaning processes was discharged to the PGDP sanitary sewer system for treatment at an PGDP’s on-site water treatment plant. True or False?

In 2016, the maximum PGDP technetium-99 groundwater activity was found in the vicinity of the C-400 Cleaning Building. True or False?

Table ___ summarizes the cumulative gallons of TCE removed from PGDP groundwater over the course of year that the removal activities were conducted.

Remedial Actions, ongoing groundwater pump and treat actions and remedial method demonstrations have removed ______________ gallons of TCE from PGDP groundwater.

Rail tankers can transport up to _________ gallons of chemicals.

7. QUALITY ASSURANCE

The PGDP Site maintains a Quality Assurance (QA) /__ __ (_ _) Program to ________ the integrity of data generated by the Environmental Monitoring Program.

The QA/QC Program addresses each aspect of the Environmental Monitoring Program from ____________ collection to _____ ______.

What 7 sources for QA/QC Program requirements and guidelines are cited in the ASER?

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________

7.1 FIELD SAMPLING QUALITY CONTROL

7.1.1 Data Quality Objectives and Sample Planning

The DQO Process is a step-by-step planning approach to develop sampling designs for ***data*** collection activities that support decision making. https://vsp.pnnl.gov/help/vsample/Data_Quality_Objectives_DQO_process.htm

Data Quality Objectives are used in project planning to determine 6 components of project sampling and analysis:

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________

Samples collected at PGDP are each assigned a unique sample _____________.

The PGDP uses an electronic database, the _________ ________ ________ _______, to manage its environmental data.

7.1.2 Field Measurements

Field measurements are measurements made in the ____________.

Groundwater and surface water monitoring require field measurements be collected including:

1. ___________________
2. ___________________
3. ___________________
4. ___________________
5. ___________________
6. ___________________
7. ___________________
8. ___________________
9. ___________________

7.1.3 Sampling Procedures

Sample media refers to (four categories):

1. ___________________
2. ___________________
3. ___________________
4. ___________________

Sampling methods are ________ specific.

A '_______ of ________' is established track the collection and handling of each sample collected.

7.1.4 Field Quality Control Samples

The PGDP Quality Control Program targets what percent of total samples be collected as QC samples?

Analytical results of QC samples are evaluated to determine if sampling methods biased sample results. True or False.

Identify 3 types of Field QC samples.

1. ____________________
2. ____________________
3. ____________________

7.2 ANALYTICAL LABORATORY QUALITY CONTROL

7.2.1 Analytical Procedures

A sample matrix is the component of specific media that is being analyzed in the laboratory. True or False?

The sediment media type may have a liquid and solid component that require chemical analysis. True or False?

Groundwater and surface water samples may require chemical specific analytical methods for total, dissolved and suspended chemical(s). True or False?

The primary EPA issued guidance document that identifies matrix and chemical specific laboratory analytical methods is SW-______. https://www.epa.gov/hw-sw846

7.2.2 Laboratory Quality Control Samples

Identify 4 types of analytical laboratory QC samples.

1. ____________________

2. ____________________

3. ____________________

4. ____________________

7.2.3 Independent Quality Control

The Paducah Site is required by DOE and EPA to participate in independent QC programs. True or False?

7.2.4 Laboratory Audits/Sample and Data Management Organization

Laboratory audits are performed annually by the DOE Consolidated Audit Program to ensure that the laboratories are in compliance with regulations, methods, and procedures. True or False?

7.3 DATA MANAGEMENT

7.3.1 Project Environmental Measurements System (PEMS)

PGDP field, sample and laboratory data is entered into and maintained in the __________________ database.

PGDP field, sample and laboratory data used for reporting is maintained in the Oak Ridge Environmental Information System (OREIS) database. True or False?

7.3.2 Paducah OREIS

Paducah PEMS data is archived for future use in the OREIS database. True or False?

7.3.3 PEGASIS

PGDP's OREIS environmental data is accessible to site personnel, regulators, and the general PUBLIC through the Paducah Environmental Geographic Analytical Spatial Information System (PEGASIS). True or False?

On your phone or computer go to Pegasis.pad.pppo.gov

(Best on Edge, IE and iPhone Safari. Some functions on Chrome may/may not work based on Chrome security settings)

1. Choose ‘What is PEGASIS’ link in right hand column
2. What organization developed the data and GIS system that eventually became PEGASIS?

Next use this link to look at the GIS map of the site:
https://pegasis.pad.pppo.gov/portal/apps/webappviewer/index.html?id=1923382d7e944d19b50db8bad354baa8

The default map shows the PGDP Site, The DOE Reservation, WKWMA, TVA and surrounding areas.

1. On layer list (right side of map), expand the ‘GIS Layers’
2. Page Down the layer list and find the ‘Flora Species’ (tree cover) and ‘Habitat’ layers
3. Turn each specific layer on and off to see the extent of areas in each layer.

Next use this link to the GIS map to view locations and media types where chemical and radionuclide samples were collected and to download data you are interested in:

https://pegasis.pad.pppo.gov/analyticaldataENH/

Page will load with map in background and Analytical Data Filter box.

Page may take a minute to load ‘Analytical Data Filter’ box that you will use to identify environmental data you are interested in)

The Analytical Data Filter box gives you choices for: media, location, chemical or radionuclide analytical results, depth, date, and/or timeframes.

Choose “Starting” and enter 01/01/89

Choose “Ending” and keep the current date that is already showing

Choose “Detects” and keep ‘all’

Choose “Fractions” and leave blank

Choose “Locations” and leave blank

Choose “Analytes by Name” and enter ‘Technetium-99’

Choose “Analytes by CAS” and leave blank

Choose “Media” and leave blank

Choose “Ending Depth” and leave blank

Click on Map and zoom in or out. The map will refresh showing locations where technetium-99 was sampled

Icons indicate which media type a 99-Tc sample was collected from at a location.

On screen go to the dark gray navigation bar at top of page and click the symbol to show the legend.

The legend identifies the media type associated with sample location icons on the map.

HOW MANY MEDIA TYPES WERE 99-Tc SAMPLES COLLECTED FROM?

There are more than 51,500 technetium-99 samples in the database.

Choose ‘Export CSV’ to download the technetium-99 records

7.3.4 Electronic Data Deliverables

Each laboratory provides the PGDP with _______ electronic data for all samples analyzed by the laboratory.

7.3.5 Data Packages

No questions. This section is incomplete. Ignore this section for the Student ASER.

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. True or False?

7.3.7 Data Verification, Validation, and Assessment

Data verification is the process of comparing a data set against standards or contractual requirements. True or False?

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. True or False?

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.

APPENDIX B - MCHS 2016-17 ASER PROJECT ACTIVITIES

Figure B.10. MCHS students study wildlife in the field at the WKWMA

Figure B.11. MCHS student learn how wildlife is trapped for study in the WKWMA

Figure B.12. MCHS student examines a trap at the WKWMA

Figure B.13. Students learning in the field at the WKWMA

Figure B.14. MCHS students getting an introduction to PGDP site before a tour.

Figure B.15. MCHS Students learn about WKWMA wildlife monitoring.

Figure B.16. Dr. Steven Price of UK Agriculture presents on the wildlife of the WKWMA

Figure B.17. MCHS students handle reptiles native to the WKWMA

APPENDIX C – RADIATION AND RADIOACTIVE MATERIALS PRIMER

Radiation 101

Kentucky Public Health

Topics of Discussion

- Radiation Fundamentals
- Radiation Effects
- Radiation Detection
- Uranium Enrichment

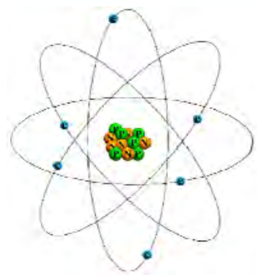
Radiation Fundamentals

The Atom

- Smallest unit of all matter
- Basic building block for everything
- Held together by forces
- When forces are broken, energy is released

Radiation Fundamentals

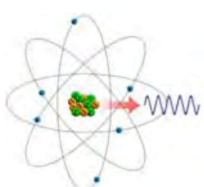
Parts of an Atom



- Protons
- Neutrons
- Electrons

Radiation Fundamentals

Stable and Unstable Atoms



- An atom with too many or too few neutrons contains excess energy and is not stable.
- Unstable atoms give off excess energy (radiation).
- Unstable atoms are radioactive.

Radiation Fundamentals

Radiation can be either non-ionizing (low energy) or ionizing (high energy)

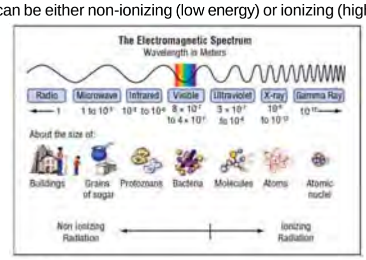
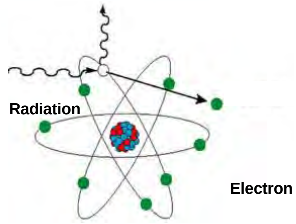


Image Credit: NASA

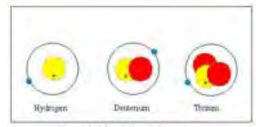
Radiation Fundamentals

Ionizing Radiation



Radiation Fundamentals

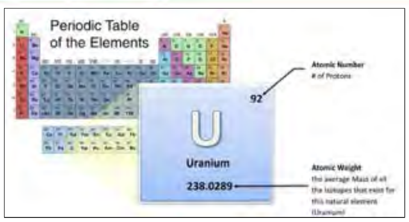
Isotopes of an element have the same number of protons in each atom but differ in the number of neutrons



Bohr model of the hydrogen isotope atoms

Isotope	a.k.a	Atomic Weight	=	# Protons	+	# Neutrons
H (Protium)	^{1}H	1	=	1	+	0
H-2 (Deuterium)	^{2}H	2	=	1	+	1
H 3 (Tritium)	^{3}H	3	=	1	+	2

Radiation Fundamentals



Isotope	a.k.a	Atomic Weight	=	#	+	#Neutrons
U-238	^{238}U	238	=	92	+	146
U-235	^{235}U	235	=	92	+	143
U-234	^{234}U	234	=	92	+	142

Radiation Fundamentals

Radioactivity

The process of unstable (radioactive) atoms trying to become stable by emitting ionizing energy

Radiation Fundamentals

Radioactive Material

Material containing unstable (radioactive) atoms

Radiation Fundamentals

"Radiological" vs. "Nuclear"

- **"Radiological"** deals with radiation or material that emits radiation

  Example Radiological WMD: "Dirty Bomb"

- **"Nuclear"** refers to processes that involve splitting a nucleus (fission) or combining nuclei of atoms (fusion)

  Example Nuclear WMD: atomic bomb

Radiation Fundamentals

Measuring Radiation

Radiation Dose

- Radiation energy absorbed by the human body
- Dose is measured in units of rem

Radiation Fundamentals

Measuring Radiation

Radiation Dose Rate or Exposure Rate

- Radiation energy received over a period of time
- Radiation dose rate is dose per time
- "Strength" of radiation at a location

Radiation Fundamentals

Radiation Dose Rate or Exposure Rate

Write	Say	Conversion
μR/h	**micro** R per hour	1 μR/h = 1/1000 mR/h
mR/h	**milli** R per hour	1 mR/h = 1000 μR/h
R/h	R per hour	1 R/h = 1000 mR/h

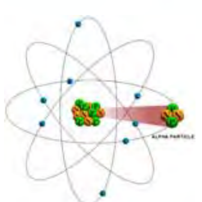
Radiation Fundamentals

Types of Ionizing Radiation

- Alpha radiation
- Beta radiation
- Gamma rays/X-rays (photons)
- Neutron radiation

Radiation Fundamentals

Alpha Radiation



- Range:
  1 to 2 inches
- Shielding:
  paper, cloth, dead layer of skin

Radiation Fundamentals

Alpha Radiation

Biological Hazard

- Not an external radiation hazard
- Easily stopped by the dead layer of skin
- Internal hazard if the material that emits the alpha radiation is ingested, injected or inhaled

Radiation Fundamentals

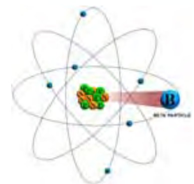
Alpha Radiation

Sources

- Uranium (nuclear power plant fuel and nuclear weapons)
- Plutonium (nuclear weapons)
- Americium (smoke detectors)

Radiation Fundamentals

Beta Radiation



- Range:
  up to 30 feet
- Shielding:
  thick clothing, <¼ inch aluminum, ¼ inch plastic

Radiation Fundamentals

Beta Radiation

Biological Hazard

- External hazard to skin and eyes
- Internal hazard if the material that emits the beta radiation is ingested, injected or inhaled

Radiation Fundamentals

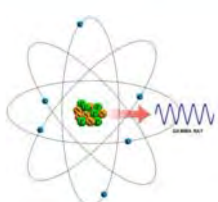
Beta Radiation

Sources

- Used nuclear reactor fuel
- Nuclear weapons fallout (strontium)
- Some industrial radioactive sources such as cesium
- Radioactive tritium in glow-in-the-dark EXIT signs, watch dials, and night-sights on firearms

Radiation Fundamentals

Gamma Radiation & X-Rays



- Range:
  Hundreds to thousands of feet
- Shielding:
  1 inch of lead, 3 inches of steel, 6 inches concrete, 1 foot of dirt

Radiation Fundamentals

Gamma Radiation & X-Rays

Biological Hazard

- Gamma radiation and X-rays easily penetrate body tissues, outside or inside of the body
- Whole body (internal and external) hazard

Radiation Fundamentals

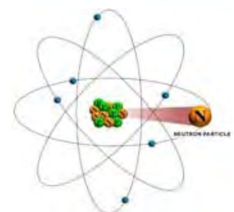
Gamma Radiation & X-Rays

Sources

- Uranium, plutonium, cobalt, and cesium
- Industrial radiation sources
- Medical sources, cancer treatment machines

Radiation Fundamentals

Neutron Radiation



- Range:
hundreds of feet
- Shielding:
10 inches of plastic, 1 foot of concrete, 3 feet of dirt, 3 feet of water

Radiation Fundamentals

Neutron Radiation

Biological Hazard

- Whole body hazard (external and internal neutrons are a whole body hazard)
- Neutrons penetrate body tissues
- Neutrons cause damage whether the material is inside or outside of the body

Radiation Fundamentals

Neutron Radiation

Sources

- Nuclear reactions inside nuclear reactor while reactor is operating
- Burst of radiation from exploding nuclear weapon
- Plutonium

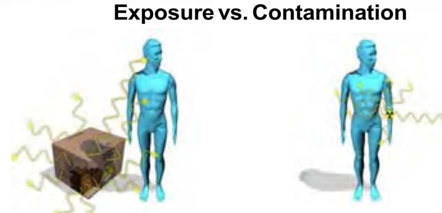
Radiation Fundamentals

Comparison of Radiation and Contaminants

- Radiation is **energy**
- Radioactive contaminants are **materials** that emit radiation
- Radioactive contaminants are radioactive atoms that get onto something unwanted or are in an uncontrolled place
- Radioactive atoms cannot be neutralized to make them non-radioactive

Radiation Fundamentals

Exposure vs. Contamination



Radiation Fundamentals

Internal Contamination and Exposure

- Radioactive material inside the body
- Both contaminated and exposed

Radiation Fundamentals

ALARA

- **A**s
  - **L**ow
    - **A**s
      - **R**easonably
        - **A**chievable

Radiation Fundamentals

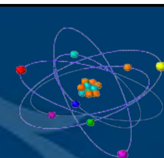
ALARA

Time - Minimize time near the source

Distance - Maximize distance from source

Shielding - Use shielding between you and source

Detection - Use to verify and identify higher than normal



QUESTIONS

Radiation Effects

Sources of Natural Background Radiation

- Cosmic Radiation
- Terrestrial Radiation
- Internal Radiation
- Radon

Radiation Effects

Cosmic Radiation

- From the sun and outer space
- Higher doses at higher elevations
- Average of 33 mrem per year

Radiation Effects

Terrestrial Radiation

Sources in the Earth's Crust

• Ground - rocks, soil, and sand

• Sources - natural radioactive elements of radium, uranium, thorium, and potassium

• Nuclear weapons fallout/Chernobyl

Radiation Effects

Internal Sources of Natural Background Radiation

Sources in the human body

• Food and water in trace amounts

• Naturally occurring radioactive materials deposited in our bodies

• Average of 29 mrem per year

Radiation Effects

Radon

• (Gas) formed from the radioactive decay of uranium in the soil

• Can collect in basements

• Emits alpha and gamma radiation

• Average of 228 mrem per year

Radiation Effects

Man-Made Sources of Radiation

• Cigarette Smoking

Up to 16 rem per year for a one-pack-a-day smoker

• Commercial Airline Travel

4 mrem per cross-country round trip

Radiation Effects

Background Dose Comparison

• Natural background 311 mrem per year

• 1 mrem dose approximately:

  • 28 hours of natural background

  • 2 to 3 hours of an airline flight

Radiation Effects

Effects of Radiation

Some cells are more sensitive:

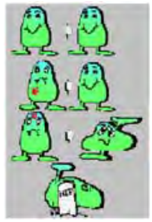
• Blood

• Cells that form sperm

• Intestinal tract

Radiation Effects

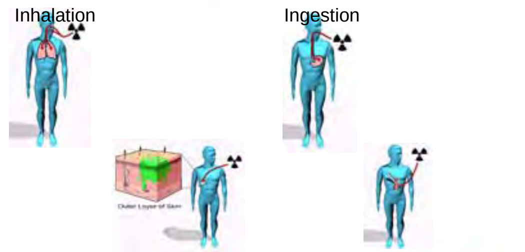
Effects on Cells Exposed to Ionizing Radiation



- No damage
- Repair and operate normally
- Damaged and operate abnormally
- Cells die

Radiation Effects

Biological Pathways



Radiation Effects

Acute vs. Chronic Radiation Doses

Acute

- Large dose
- Short time

Chronic

- Small doses
- Long time

Radiation Effects

Biological Effects of Radiation Exposure

- Damage in exposed individual
- Somatic effects
- No proven cases of genetic damage to humans passed on to future children
- Survivors of Hiroshima and Nagasaki: genetic mutations in their children no higher than the general population

Radiation Effects

Factors Affecting Cell Damage

- Total dose
- Dose rate
- Type of radiation
- Area of the body
- Cell sensitivity
- Individual sensitivity

Radiation Effects

Acute Radiation Effects Dose

Less than 30 rem

- No clinical symptoms

Between 30 and 100 rem

- *Possible* loss of appetite, nausea, and vomiting
- Temporary lowering of white cell count

Between 100 and 250 rem

- Nausea, vomiting, diarrhea
- No permanent disability

Radiation Effects

Acute Radiation Effects Dose

Between 250 and 500 rem

- Nausea, vomiting, diarrhea
- Lethal Dose 50% in 60 days $LD_{50/60}$

Advanced medical care may raise the $LD_{50/60}$ level to 800 to 900 rem

1,000 rem

- Severe nausea, vomiting, diarrhea
- Death for almost all people
- Lethal Dose 100% LD_{100}

Radiation Effects

Acute Exposure and Fatal Cancer

Dose rem (mrem)	Percent
1 (1,000)	0.08
5 (5,000)	0.4
10 (10,000)	0.8
25 (25,000)	2.0
50 (50,000)	4.0

Radiation Effects

Fatal Cancer Risk Estimates

(Example)

- 10 rem (10,000 mrem) dose – extra 0.8%
- 1,000 survivors receive 10 rem (10,000 mrem) – estimated 8 *extra* cancer deaths
- 200 cancer deaths from other causes
- 208 total cancer deaths

Radiation Effects

Chronic Radiation Dose Risks

- A small amount of ionizing radiation received over a long period of time (months, years)
- Small increase in cancer risk

Radiation Effects

Potential Effects of Chronic Radiation Dose

Biological effects from chronic doses of radiation may occur in:

- Exposed individual
- Future children of the exposed individual

Radiation Effects

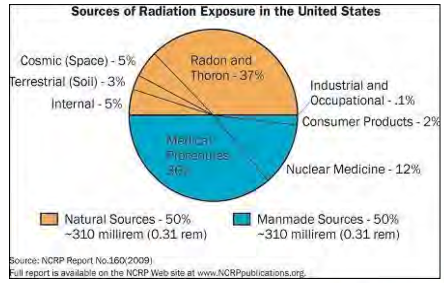
Risk in Perspective

- No increase in cancer observed at doses of 5 rem or less per year
- Somatic health effects (primarily cancer) observed only at doses more than 10 rem (10,000 mrem)
- Risk below this is speculative

Radiation Effects

Estimated Loss of Life Expectancy from Health Risks	Days
Smoking one pack a day	2250
Being 25% overweight	777
Alcohol consumption (U.S. average)	365
Agricultural accidents	320
Construction accidents	227
Automobile accidents	207
Chronic Radiation (1000 mrem per year from 18 to 65)	51
All natural hazards (earthquake, lightning, flood, etc.)	50
Chronic Radiation (100 mrem per year for 70 years)	10
All industry	7
Medical radiation	6
Drinking coffee	5

Radiation Effects



QUESTIONS

Radiation Detection

Radiological Surveys

- Radiation cannot be detected by our senses
- Survey instruments can:
  - Easily and accurately measure radiation and contamination
  - Help evaluate radiological hazards

Radiation Detection

Radiological Surveys

- Two categories of instruments available:
  - Those that measure exposure
  - Those that measure contamination
- Some survey instruments are designed to do both

Radiation Detection

Contamination Survey Instruments

- Typically read in counts per minute (CPM) or kilo-counts per minute (kCPM)
- Many digital instruments auto-scale
- Not designed for measuring radiation exposure
- Typically capable of detecting alpha, beta and gamma/x-ray radiation

Radiation Detection

Application of Contamination Survey Instruments

- Locating contamination on personnel and equipment
- Determining the effectiveness of decontamination
- Verifying contamination control boundaries
- Determining the extent and magnitude of a contaminated area

Radiation Detection

Use of Contamination Survey Instruments

- Verify instrument is on and set to the lowest/most sensitive scale
- Check for audio and visual response
- Verify background radiation level
- Hold probe 1/2 inch from surface
- Move probe slowly, 1-2 inches per second

Radiation Detection

Radiation Exposure Survey Instruments

- Typically read in µR/hr, mR/hr or R/hr
- Many instruments auto-scale
- Best suited for use when entering a field of radiation
- Typically capable of detecting gamma/x-ray radiation, but some specialized instruments are capable of detecting beta or neutron radiation

Radiation Detection

Application of Radiation Exposure Survey Instruments

- Establishing control zone boundaries
- Controlling personnel exposure
- Locating sources of radiation

Radiation Detection

Use of Radiation Exposure Survey Instruments

- Start with low-range survey instrument
- Verify instrument is on and set to the lowest/most sensitive scale
- Check for audio and visual response
- Verify appropriate response to check source

Radiation Detection

Radioisotope Identifiers

- More advanced type of radiation detection device used for the detection and identification of gamma-emitting radioisotopes
- With proper training, users can search, measure, and identify nuclides for risk assessment

Radiation Detection

Personal Radiation Detectors

- Small, pocket sized device that alerts the user to the presence of elevated radiation levels and possible radioactive material
- Extremely sensitive to low levels of gamma radiation

Radiation Detection

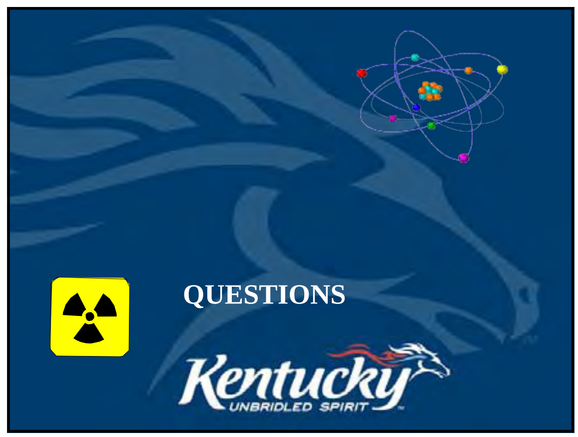
Electronic Dosimeter

- Measures accumulated dose
- Utilizes digital readout
- Audible response – chirp rate varies with radiation dose rate

Radiation Detection

Portal Monitors

- Passive radiation detection device
- Quickly screens for the presence of radioactive material
- Allows for screening of large groups of people
- Can be setup on location in under 5 minutes



Uranium Enrichment

Fission

- A self-sustaining nuclear reaction caused by radioactive decay or induced, for example, by bombardment with neutrons
- Results in the nucleus of a particle splitting into smaller parts which are ejected along with energy
- Releases large amounts of energy

Uranium Enrichment

Fission

- Nuclear power reactors harness the energy and heat from nuclear fission to produce the steam that runs turbines which, in turn, generate electricity
- The amount of available energy contained in nuclear fuel is millions of times the amount of available energy contained in a similar mass of chemical fuel such as petroleum or natural gas
- One kilogram of enriched uranium-235 has the capacity to produce as much energy as 1,500,000 kilograms (1500 tons) of coal

Uranium Enrichment

Naturally Occurring Uranium

- Naturally occurring uranium consists of three isotopes
  - U-238 The most abundant; over 99% of naturally occurring uranium
  - U-235 The only fissile naturally occurring isotope; approximately 0.72% of naturally occurring uranium
  - U-234 The least abundant; approximately 0.0055% of naturally occurring uranium

Uranium Enrichment

Fissile Uranium

- Fissile material can sustain a nuclear reaction which results in a release of energy as heat
- The heat from fission is used to drive turbines and generate electricity
- The Paducah Gaseous Diffusion Plant (PGDP) enriched uranium from the natural abundance of fissile U-235 for use as a fuel source

Uranium Enrichment

Enriched U-235

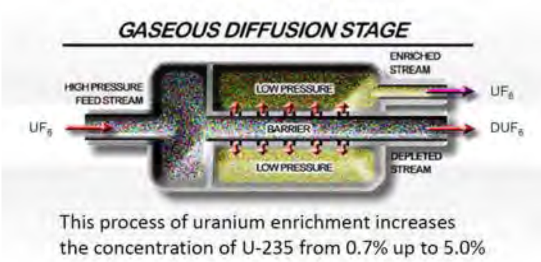
- The Paducah Gaseous Diffusion Plant enriched uranium from the natural abundance of fissile U-235 for use as a fuel source
- The natural abundance of U-235 was increased from 0.7% to 5% using the gaseous diffusion process

Uranium Enrichment

Enriched U-235

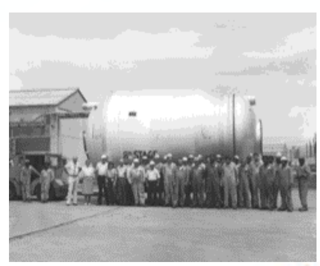
- Uranium was blended with fluorine gas at high temperature and pressure to produce uranium hexafluoride gas (UF6)
- U-235 was separated from U-238 by diffusion through membranes (a stage)
- A volume of UF6 gas is passed through >1,800 stages before enrichment is complete

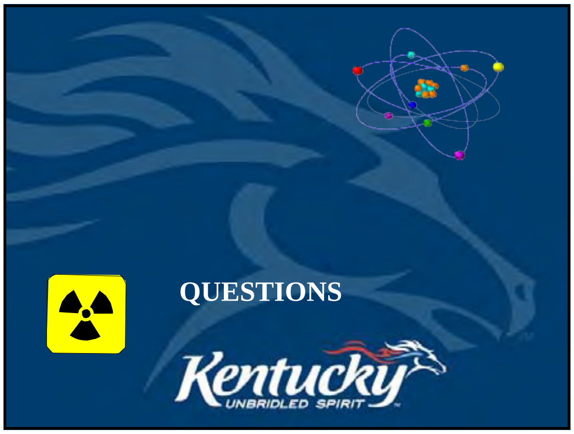
Uranium Enrichment



Uranium Enrichment

The 8th stage convertor (of 1,760) from PGDP's diffusion process




QUESTIONS
Kentucky
UNBRIDLED SPIRIT