Bettis Atomic Power Laboratory

Environmental Monitoring Report

Calendar Year 2018

Prepared for the U. S. Department of Energy
by Fluor Marine Propulsion, LLC

FLUOR®

BETTIS ATOMIC POWER LABORATORY

ENVIRONMENTAL MONITORING REPORT

CALENDAR YEAR 2018

Prepared for the U. S. Department of Energy by
Fluor Marine Propulsion, LLC
Bettis Atomic Power Laboratory
West Mifflin, Pennsylvania 15122-0079

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COMMON ABBREVIATIONS

Ci	curie
µCi	microcurie = 1.0×10^{-6} curie
µCi/ml	microcuries per milliliter
µg/l	micrograms per liter
mg/l	milligrams per liter
mosm/kg	milliosmoles per kilogram
mrem	millirem
ml	milliliter
mg/kg	milligrams per kilogram
pCi	picocurie = 1.0×10^{-12} curie
pCi/g	picocuries per gram
pCi/l	picocuries per liter

LIST OF ACRONYMS

ACCD	Allegheny County Conservation District
ACHD	Allegheny County Health Department
ALARA	As Low As Reasonably Achievable
CAA	Clean Air Act
CACO	Consent Agreement/Consent Order
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CMIO	Corrective Measures Implementation Order
CMS	Corrective Measures Study
DCE	1,2-dichloroethylene (cis-1,2-dichloroethylene; trans-1,2-dichloroethylene)
DLC	Decision Level Concentration
DOE	U.S. Department of Energy
EHS	Extremely Hazardous Substances
EPA	U.S. Environmental Protection Agency
EPCRA	Emergency Planning and Community Right-to-Know Act
ERA	Environmental Resource Associates
ESH	Environmental, Safety and Health
ESHMS	Environmental Safety and Health Management System
ESVE	Enhanced Soil Vapor Extraction
FMP	Fluor Marine Propulsion, LLC
HEPA	High Efficiency Particulate Air
HRS	Hazard Ranking System
IWS	Inactive Waste Site
MEL	Materials Evaluation Laboratory
NARAC	National Atmospheric Release Advisory Center
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NNL	Naval Nuclear Laboratory
NNPP	Naval Nuclear Propulsion Program
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
NRLFO	Naval Reactors Laboratory Field Office
PADA	Pennsylvania Department of Agriculture
PADEP	Pennsylvania Department of Environmental Protection
PA/SI	Preliminary Assessment and Site Inspection
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyls
PCE	Tetrachloroethylene (Perchloroethylene)
PNR	Pittsburgh Naval Reactors Office
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SARA	Superfund Amendments and Reauthorization Act
SIS	Springwater Intercept System
TCE	Trichloroethylene
TLD	Thermoluminescent Dosimeter
VNG	Valley National Gases (currently known as Matheson Valley)
VOC	Volatile Organic Compound

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EXECUTIVE SUMMARY

The results of the 2018 radiological and nonradiological environmental monitoring programs for the Bettis Atomic Power Laboratory (Bettis) are summarized below. Tables 1 and 2 summarize the major elements of the environmental monitoring programs.

Liquid Effluents (Other than to Sanitary Sewer)

Approximately 43,500,000 gallons of noncontact cooling water, process wastewater, and stormwater runoff were released to the environment via the Bull Run (Outfall 001) Monitoring Station. Radioactivity concentrations for all radionuclides of concern were either below decision level concentrations (DLCs) or were typical of background levels in city water and precipitation. The DLC is the minimum value of the measured analyte concentration that provides a degree of confidence that a positive amount of analyte is present in the material analyzed. Monitoring data for chemical constituents in liquid effluents demonstrated that these effluents did not have any significant impact on the quality of the receiving water. These results demonstrated compliance with the U.S. Department of Energy (DOE) standards and the Site's National Pollutant Discharge Elimination System (NPDES) Permit.

Stormwater runoff via Stormwater Outfalls 003, 005, 006 and 008 and treated groundwater via Outfall 007 were released to the environment. These discharges were made in accordance with the Site's NPDES Permit.

Sanitary Sewer Discharges

Sanitary sewage was discharged to a Publicly Owned Treatment Works. Wastes discharged to the sanitary system were in compliance with applicable regulations.

Groundwater

Analyses of a number of the groundwater samples from five water-bearing zones beneath the Site show low levels of strontium-90 (Sr-90) similar to that found from worldwide testing of nuclear weapons. A very small portion of the uppermost water-bearing zone contained low levels of Sr-90 due to small inadvertent laboratory releases in the 1950s and 1960s. The levels of Sr-90 are well below the 10 CFR 20 concentrations for water in unrestricted areas; therefore, these levels have no adverse effect on human health or the environment.

The results of the majority of the groundwater analyses for a variety of chemicals were less than practical quantitation limits. Some analyses indicated the presence of volatile organic compounds (VOCs), primarily tetrachloroethylene (PCE), which are associated with past degreasing operations performed by Bettis and possibly by prior tenants when the Site was an airfield. The presence of these chemicals is not due to current Site operations.

TABLE 1

RADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM[1]

Media Monitored	Analysis Frequency	Routine Analyses
LIQUID EFFLUENTS • Bull Run Monitoring Station • Sanitary Sewer (Manhole 109)	Monthly	Gross Alpha, Gross Beta
	Quarterly	Strontium-90, Gamma
• Outfall 008	Annually	Gross Alpha, Gross Beta, Strontium-90, Gamma
• Sanitary Sewer (SAN10)	Semiannually	Gross Alpha, Gross Beta
LIQUID INFLUENTS • City Water • Precipitation	Monthly	Gross Alpha, Gross Beta
	Quarterly	Strontium-90, Gamma
GROUNDWATER • Wells/Springs[2]	Annually	Gross Alpha, Gross Beta, Strontium-90, Gamma, Uranium-233/234, Uranium-235, Uranium-238
SURFACE WATER • Bull Run Stream (BR5)		
STREAM SEDIMENT AND VEGETATION • Bull Run Stream • Northeast Area Stream • Thompson Run Stream • Off-site Control Location	Semiannually (Sediment)	Gross Alpha, Gross Beta, Gamma
	Annually (Sediment)	Strontium-90 (Bull Run and off-site control location only)
	Annually (Vegetation)	Strontium-90, Gamma
SEDIMENT • Bull Run Monitoring Station • Storm Sewer Components	Annually	Gross Alpha, Gross Beta, Gamma, Strontium-90
SOIL • Runoff Area Below the IWS	Every Two Years (2020)[3]	Gross Alpha, Gross Beta, Strontium-90, Gamma, Uranium-233/234, Uranium-235, Uranium-238
RADIATION • Site Perimeter	Continuously	Gamma Radiation
• Bull Run Stream	Every Fifth Year (2021)[3]	
• Runoff Area Below the IWS	Every Fifth Year (2022)[3]	
AIRBORNE EFFLUENT • Particulate Activity	Weekly	Gross Alpha, Gross Beta
	Quarterly	Gross Alpha, Gross Beta Strontium-90, Gamma
• Radon	Annually	Radon-220, Radon-222
AIRBORNE (Ambient Background) • South Park, PA • West Mifflin, PA	Weekly	Gross Alpha, Gross Beta

NOTES:

(1) The monitoring methods used in this program are "grab and composite" sampling. The particulate activity in the airborne effluent is monitored on a continual basis.

(2) Water from approximately one-third of the wells in the monitoring program is analyzed for strontium-90, uranium-233/234, uranium-235 and uranium-238 each year; all wells in the program will be analyzed for these parameters over a three year period.

(3) Indicates year when sampling or monitoring is next due.

TABLE 2

NONRADIOLOGICAL ENVIRONMENTAL MONITORING PROGRAM(1)

Media Monitored	Analysis Frequency	Routine Analyses
LIQUID EFFLUENTS • Bull Run Monitoring Station	Semimonthly	Dissolved oxygen, fecal coliforms, oil and grease, pH, suspended solids, temperature
	Semiannually	Alkalinity, aluminum, ammonia, chloride, hardness, iron (dissolved), iron (total), osmotic pressure, total dissolved solids
	Annually	Antimony, arsenic, base neutral/acids, beryllium, cadmium, chromium (hexavalent), chromium (total), copper, cyanide (free), lead, mercury, nickel, pesticides, polychlorinated biphenyls (PCBs), selenium, silver, thallium, volatile organic compounds, zinc
• Springwater Intercept System (SIS) Outfall 007	Semimonthly	Iron (dissolved), pH, suspended solids, tetrachloroethylene, trichloroethylene, 1,2-dichloroethylene (cis-1,2-dichloroethylene, trans-1,2-dichloroethylene)
• Sanitary Sewer (SAN-10)	Semiannually	Biochemical oxygen demand, chloride, dissolved oxygen, hardness, oil and grease, pH, suspended solids, temperature
	Annually	Mercury, silver
LIQUID INFLUENTS • City Water	Semimonthly	Dissolved oxygen, fecal coliforms, oil and grease, pH, suspended solids, temperature
	Semiannually	Alkalinity, aluminum, ammonia, chloride, hardness, iron (dissolved), iron (total), osmotic pressure, total dissolved solids
	Annually	Antimony, arsenic, base neutral/acids, beryllium, cadmium, chromium (hexavalent), chromium (total), copper, cyanide (free), lead, mercury, nickel, pesticides, polychlorinated biphenyls (PCBs), selenium, silver, thallium, volatile organic compounds, zinc
GROUNDWATER • Wells • SIS Springs	Annually	Volatile organic compounds
SEDIMENT • Bull Run Monitoring Station • Storm Sewer Components	Annually	Volatile organic compounds
• Bull Run Stream (BR1, BR5)	Annually	Volatile organic compounds
• Residual Materials in the Inactive Coke Gas Lines	Annually	Volume of deposited material
SURFACE WATER • Bull Run Stream (BR1, BR5)	Annually	Volatile organic compounds

NOTES:

(1) The monitoring method used in this program is "grab" sampling except for suspended solids sampling at the Bull Run Station. These samples were collected as composite samples over a 24-hour period.

Sediment, Soil, and Vegetation

Analyses for radioactivity in the Site's effluent streambeds demonstrated that there were no significant changes in the low levels of radioactivity from historical operations in the streambeds during 2018.

Analyses of vegetation collected in and along the Site's effluent streams did not detect any radioactivity in excess of natural background levels.

Analyses of storm sewer sediment for radioactivity showed low levels of cesium-137 (Cs-137) radioactivity consistent with levels of Cs-137 found in the environment due to fallout and also to previous results attributed to historic Bettis operations during the 1950's and 1960's. These radioactivity concentrations are less than those found naturally occurring in loose leaf spinach.

Analyses of storm sewer sediment for a variety of chemicals showed the presence of some of the contaminants of concern (PCE, dichloroethylene (DCE), polychlorinated biphenyls (PCBs), and mercury) above the analytical laboratory's minimum quantitation levels in a few samples. The concentrations of these chemicals were consistent with previous results.

Analyses of Bull Run stream sediment detected the presence of PCE at levels consistent with previous detections in the stream sediment and with levels found in site soils.

Radiation

Radiation surveys and thermoluminescent dosimetry data around the Site perimeter demonstrated that radiation levels were typical of natural levels of radioactivity for Western Pennsylvania. Perimeter thermoluminescent dosimetry data also confirmed that Site operations did not cause any measurable change in the natural radiation levels surrounding the Site.

Airborne Effluents

Radioactivity in Site airborne effluents was controlled using high efficiency particulate air (HEPA) filters to maintain particulate radioactivity releases to as low as reasonably achievable (ALARA). The amount of long-lived (>1 day half-life) particulate radioactivity released in airborne effluents was approximately 1.73×10^{-6} curies (Ci) in 2018, or approximately equal to the amount of radioactivity contained in a typical household smoke detector. Comparison of the Site's airborne effluents with background air samples showed that the Site's average airborne particulate effluent was more than 10 times lower than natural background airborne particulate radioactivity due to HEPA filtration of the ventilation systems.

Nonradiological constituents in Site emissions for Site fuel combustion and heating units were estimated utilizing U.S. EPA emission factors and were well below applicable EPA and Allegheny County standards. Operation of the Site's fuel combustion and heating equipment was conducted in accordance with applicable regulations and permits.

Risk Assessment

A risk assessment was approved by the EPA in 1994 as part of the Site's Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI). The assessment determined the "reasonable

maximum exposure" of on-site and off-site populations to chemical residues in the environment at the Site.

The assessment concluded that chemical residues in the environment at the Site did not pose significant health risks to potentially exposed populations using "reasonable maximum exposure" assumptions. The only study area where the carcinogenic risk estimate exceeded the EPA screening criterion of 1.0×10^{-6} (one chance in a million) was a small area of soil in a drainage ditch below the Inactive Waste Site (IWS), with a maximum carcinogenic risk of about 2.0×10^{-5}. However, an individual must be exposed (skin contact, ingestion, and inhalation) for 250 days/year for 25 years to achieve this risk; a situation that would no longer be possible due to the installation of the flow separator in the ditch which covers the affected soil. The risk of personnel exposure to the chemical residues in the drainage ditch area is far less than 1.0×10^{-6}.

The 2018 monitoring results support the conclusions of the 1994 risk assessment.

Dose-to-Man

Radiation exposure to the general public from Site airborne releases was too low to measure and could only be estimated using conservative, EPA authorized calculational models. The resultant evaluation of all exposure pathways conservatively estimated a maximum annual hypothetical effective dose equivalent range of 0.185 to 1.20 millirem (mrem) to an individual off-site. At the larger value of 1.20 mrem, the effective dose equivalent is only 1.2% of the numerical limit established for members of the general public by the Nuclear Regulatory Commission (NRC) and the DOE for DOE facilities such as Bettis. The annual collective effective dose equivalent to the population from Site operations within a 50-mile radius of the Site was conservatively estimated to be about 2.43 person-rem which is negligible when compared to the approximately 900,000 person-rem received by this same population from natural background radiation.

Chemical and Hazardous Waste

A waste minimization program is in place to minimize the generation of chemical and hazardous wastes. These wastes were handled, controlled, and stored by trained personnel in accordance with applicable State regulations and permits. In addition, these wastes were not disposed of on the Site. Approximately 10,750 pounds of hazardous wastes were shipped off-site to permitted facilities for final treatment and disposal. Of this amount, approximately 1,290 pounds of the total hazardous wastes disposed resulted from the disposal of soil, debris, and groundwater that was generated from remediation efforts. The waste vendors utilized Federal and State permits.

Radioactive Waste

The generation of low-level radioactive waste continues to be minimized by limiting the materials that could become contaminated and by implementing various waste volume reduction techniques. Radioactive waste generation increases, however, when performing increased remediation of inactive facilities. Radioactive waste generated on-site is shipped off-site for disposal. A total of approximately 1,442 cubic meters of the low-level radioactive waste generated on-site during 2018 was packaged in various type containers, which comply with U.S. Department of Transportation specifications, and shipped to a DOE-owned disposal facility. When necessary, small amounts of radioactive liquids were solidified prior to shipment off-site for disposal.

Off-site shipments of radioactive waste were controlled by written procedures to ensure compliance with State and Federal regulations and the disposal sites' criteria.

Mixed Waste

Mixed waste is waste that is both RCRA hazardous and radioactive. In 1995, the DOE voluntarily agreed to apply Pennsylvania Department of Environmental Protection (PADEP) requirements to the hazardous constituents of mixed waste. In addition, the U.S. DOE Naval Reactors Laboratory Field Office (NRLFO), and the EPA signed a Consent Agreement/Consent Order (CACO) for the storage and treatment of mixed wastes that are generated at the Site. Pennsylvania received mixed waste regulatory authority from the EPA in November 2000. In September 2001, the PADEP issued a revised hazardous waste storage permit that incorporated relevant requirements of the Federal Facility Compliance Act. The CACO was terminated on January 15, 2002. A Site Treatment Plan for all of the Site's mixed wastes continues to be implemented in accordance with the Permit. Mixed wastes are not disposed of on-site. A mixed waste management program is in place to minimize generation of these wastes. In 2018, there were three shipments totaling approximately 3.1 cubic meters of various mixed wastes sent for treatment and disposal.

Environmental Assessments

In 1988, a *Preliminary Assessment and Site Inspection (PA/SI) Report* was completed for the Site to meet the requirements of Section 120 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). During 1989, EPA completed their review of the Site's PA/SI and concluded that no further action under CERCLA was required for the Site.

In 1990, NRLFO and EPA Region III signed a Consent Order to conduct a RFI and Corrective Measures Study (CMS). The purpose of the RFI was to characterize the chemical residues in the environment at the Site and the purpose of the CMS was to determine site-specific remedial alternatives. The investigation of groundwater, surface water, soil, sediment, and air specified in the RFI work plans was completed in 1993. The Final RFI Report was approved by the EPA in August of 1994. The RFI report stated that some of the groundwater under the Site and some soil areas contain low levels of chemical residues. The most prevalent residue is PCE which is the same solvent used to dry-clean clothing. The report included an assessment of risk to on-site and off-site populations from exposure to the chemical residues. This risk assessment concluded that there are no areas on-site or off-site which present a risk to human health that exceeds the EPA's acceptable risk criteria.

The Final CMS Report was submitted to the EPA in November 1994 and approved by the EPA in March 1995. This report recommended actions to ensure the risks to human health will remain low and to further reduce the chemical residues in the environment.

The EPA issued its preliminary recommendations for corrective measures in September 1995 and requested public comment on the recommendations. The EPA responded to public comments, issued its final recommendations for corrective measures, and terminated the Consent Order in 1997. Bettis proactively implemented or completed most of the final recommended corrective measures prior to signing a Corrective Measures Implementation Order (CMIO), which was effective on April 16, 2001. Actions covered under the CMIO include soil vapor extraction of a landfill, performance of a groundwater study below the IWS, and continuation of routine environmental monitoring. Construction of the soil vapor extraction system was completed and the system was placed in operation in 2004. On

April 6, 2011, the Enhanced Soil Vapor Extraction (ESVE) system was shut down after reaching the ALARA criteria established for the system. Both the EPA and the PADEP agreed that the ESVE operations be permanently terminated and that the system be removed. System removal activities were completed on September 11, 2012.

The groundwater study below the IWS was completed in 2003 and the study results issued to the EPA. The Bettis Atomic Power Laboratory recommended installation of a flow separator in the wet-weather ditch to preclude the mixing of seepage containing trace levels of site residues with surface water that could potentially carry the seepage off-site. The EPA subsequently determined and documented in a supplemental Statement of Basis that, based on additional investigations, groundwater impacted by the IWS does not present an unacceptable risk and that further action is limited to monitoring Matheson Valley (formerly known as Valley National Gases (VNG)) property annually to confirm the absence or presence of water supply wells or plans to install such wells. Any use or planned use of groundwater will be reported to the EPA. To be further protective of the environment, Bettis developed plans and, in 2010, constructed the flow separator after obtaining PADEP concurrence that this action is an acceptable measure to preclude the off-site migration of groundwater seepage and sediment. Further, sampling of water and sediments in runoff associated with the former wet-weather ditch has been discontinued following installation of the flow separator as agreed by the EPA.

Bettis completed the final corrective action of the CMIO in September 2012. Some corrective actions within the CMIO require the continuation of environmental monitoring and maintaining administrative controls; in August, 2013, the EPA issued a Corrective Action Permit (CAP) that maintains these controls. On September 11, 2013, the EPA concluded that all the terms of the 2001 CMIO had been satisfied and issued a letter terminating the agreement between the EPA and the Laboratory.

Compliance Summary

During 2018, Site operations remained in compliance with existing permits and applicable regulations governing use, emission, transportation, and disposal of solid, liquid, and gaseous materials and wastes.

Conclusion

Operations at the Bettis Atomic Power Laboratory during 2018 did not result in any significant release of radioactivity or hazardous materials to the environment. Operations also did not have any adverse effect on human health or the quality of the environment at the Site or in the surrounding communities.

INTRODUCTION

The Bettis Atomic Power Laboratory is owned by the U.S. DOE and is operated under contract by Fluor Marine Propulsion, LLC (FMP). The first nonagrarian use of the Bettis Atomic Power Laboratory (Bettis) Site was as an airfield which operated from approximately 1926 until 1948. This private airfield served mainly small, privately-owned planes. The general pattern of buildings and roadways currently existing on-site is based on the original airfield design.

The Bettis Atomic Power Laboratory was organized in 1948 through the joint efforts of Westinghouse Electric Corporation, the Navy, and the Atomic Energy Commission. Westinghouse acquired title to the Bettis airfield property (~146 acres) and associated buildings in May of 1949. Additional properties were purchased in 1952. In 1957, the approximately 202 acres of land were deeded to the Federal Government. In 2002, approximately 5 acres of undeveloped property in a secluded area adjacent to and down hill from the Bettis Site were purchased. In 2008, an additional 0.5 acre of property was purchased on the southwest corner of the site to improve the Laboratory's security posture. All grounds, buildings, and equipment on the Site are the property of the Federal Government. In 2016, the Naval Nuclear Propulsion Program (NNPP) began using "Naval Nuclear Laboratory" to refer to the collective operations of the four U.S. DOE sites that perform NNPP work and the personnel operating at the associated locations.

The primary mission of the Bettis Atomic Power Laboratory has always been directed toward the design, development, testing, and operational follow of nuclear reactor propulsion plants for naval surface and submarine vessels. Specifically, the Laboratory exists to support this nation's capability to deploy and maintain a modern nuclear Navy. In addition to the primary objective of continuing work in the development of the nuclear Navy, the Laboratory has also played a role in the development of the first U.S. full-scale nuclear power plant for civilian use, the Shippingport Atomic Power Plant.

This document summarizes the 2018 results of the radiological and nonradiological environmental monitoring programs at the Site. This report also discusses the Site programs for handling and off-site disposal of radioactive waste, chemical and hazardous waste, and mixed waste.

SITE BACKGROUND AND ENVIRONMENTAL SETTING

The Site is situated on an approximate 208-acre tract of land in the Borough of West Mifflin, and is located approximately eight miles southeast of the downtown section of Pittsburgh, Pennsylvania. Figure 1 shows the location of the Site with respect to the surrounding communities, and Figure 2 shows the land uses immediately adjacent to the Site. A heavily wooded area borders the Site on the east. Most of this property is owned by the Borough of West Mifflin and a portion of this property has been developed into the West Mifflin Community Park. A fence has been erected to prevent inadvertent access to the Site property from the park area. An industrial district is located along the northern boundary of the Site. Commercial and residential developments border the Site on the south and west. The land use of the region surrounding the Site is largely industrial and residential. The total population within a 50-mile radius of the Site based on the 2010 census is approximately 3,000,000.

Physiography

Physiography refers to the natural physical landforms of an area. The Site is located within Allegheny County, Pennsylvania, which is situated within the Allegheny Plateau physiographic province of North America. Stream erosion of a formerly raised plateau produced the present rugged land surface. The geologic formations are generally flat-lying, or gently folded and inclined. Stream frequency and the percentage of the land found in slopes decrease with distance from the major drainage ways, such as the Monongahela River.

Topography

The Site is located approximately 6,000 feet northwest of the Monongahela River. The maximum elevation at the Site is approximately 1,200 feet above sea level. The minimum elevation, approximately 975 feet above mean sea level, occurs on the northern site boundary. The normal pool elevation of the Monongahela River near the Site is approximately 720 feet above sea level. Thus, the developed portions of the Site are approximately 480 feet above the surface of the Monongahela River.

Surface drainage at the Site is primarily toward the east, discharging into the Bull Run Stream and its tributaries. The principal sources of water in the Bull Run Stream originating from the Site include once-through, noncontact cooling water, stormwater runoff, and process water. The Bull Run Stream flows about 1.4 miles before joining the Thompson Run Stream which empties, about 2.6 miles downstream, into the Monongahela River in the City of Duquesne. A narrow, mostly sloped area that includes a small developed portion of the Site drains northwest toward the Thompson Run Stream. The Monongahela River is used as a raw water source for public water supply serving the Site and some surrounding communities.

Because of the location and elevation of the Site, flooding from local streams or rivers is not possible. Some minor bank overflowing of the Bull Run Stream may occur downstream from the Site during heavy rainfall.

Several springs are present on the Site property. The largest of these, Buono Spring, RQ-20 Spring, and Northeast Spring, are on the eastern, undeveloped portion of the Site. These are permanent springs with varying, but very low flows that are reflective of the seasons and precipitation events. In 1997, the SIS was constructed to collect these springs and other seeps. The water is treated by air stripping to remove VOCs and the water is discharged to the Northeast Stream via the NPDES Outfall 007.

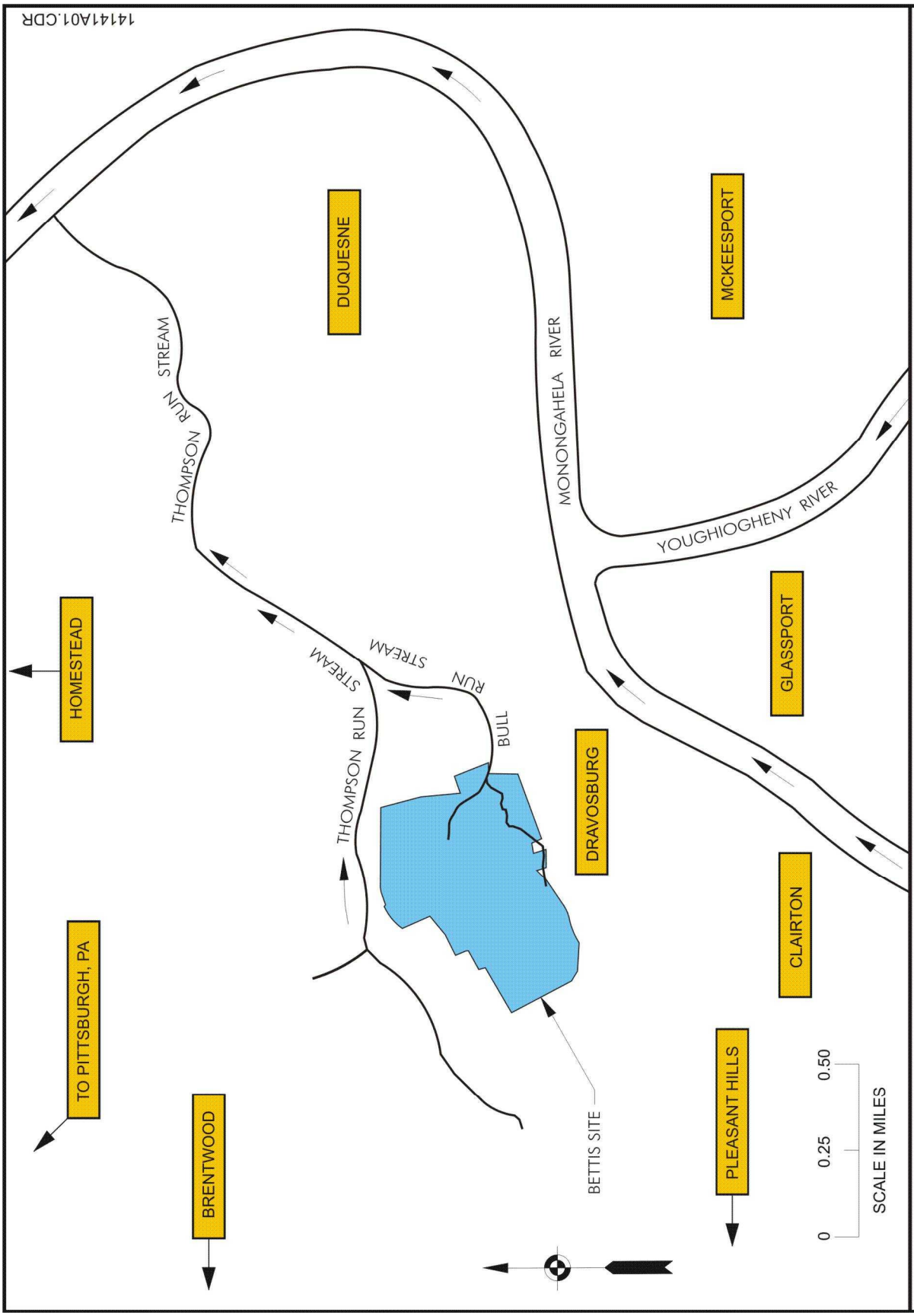

FIGURE 1 RELATIONSHIP OF THE BETTIS SITE TO THE SURROUNDING COMMUNITIES

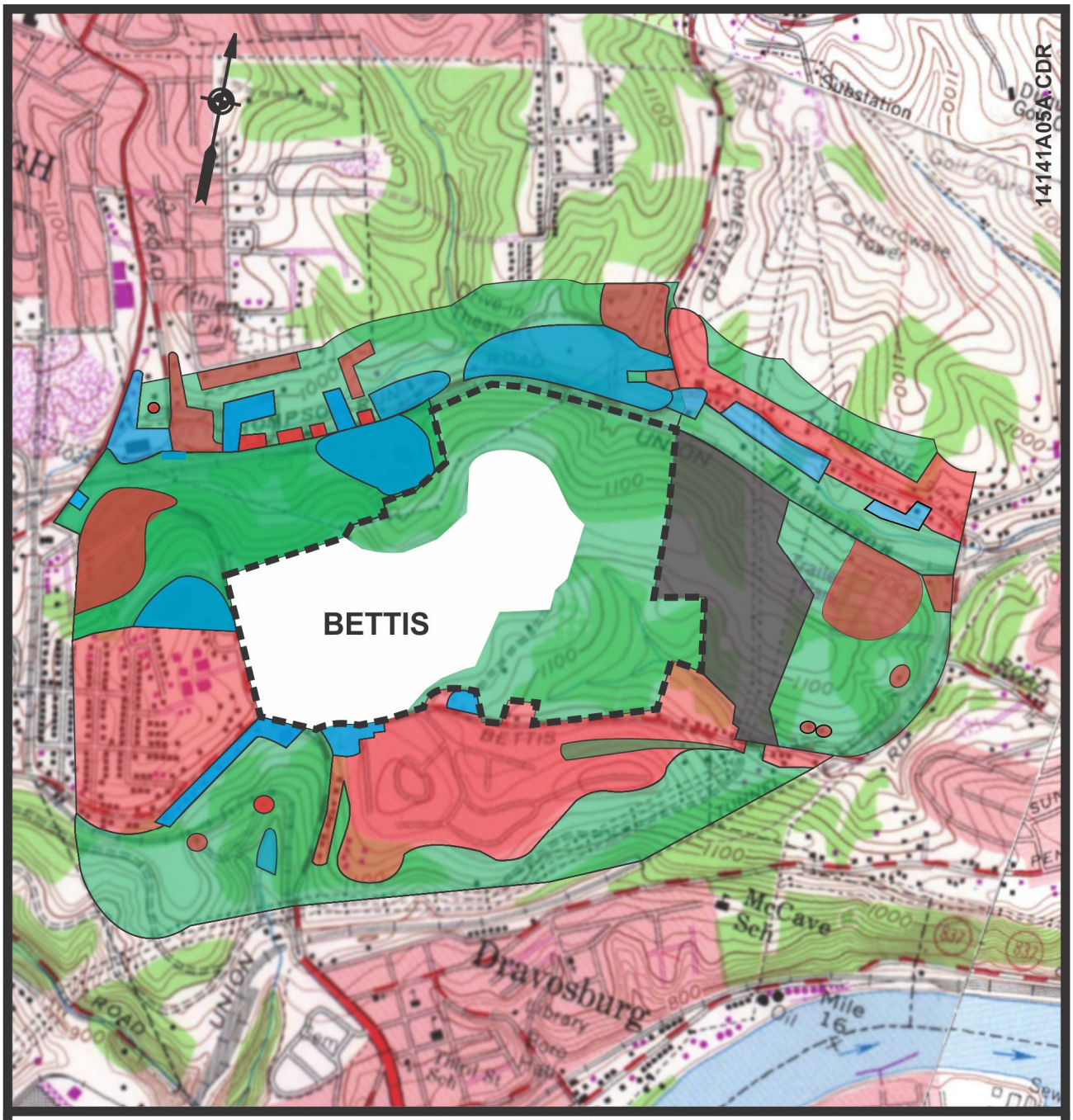

FIGURE 2 LAND USES IMMEDIATELY ADJACENT TO THE BETTIS SITE

Soils

The soils at the Site are residual in origin or are the result of filling operations. The residual soils were formed by weathering of the underlying Monongahela Group bedrock. The soils on-site are classified as the Culleoka and Urban Land-Guernsey soils. The Culleoka soils are characterized as moderately deep, well-drained soils formed from shale and fine-grained sandstone bedrock. They generally occur on upland slopes, have moderate permeability, and normally have a water table below four feet throughout the year. The surface soil can be described as dark brown, granular silt loam, while the subsoil is yellowish-brown, blocky silt loam to channery clay loam. The substrata consist of yellowish-brown, massive, very channery clay loam.

The Urban Land-Guernsey soils are described as variable, consisting of disturbed land resulting from cut and fill operations and subsequent coverage with urban works. These soils occur in a complex pattern with Culleoka soils which are described above. The Guernsey soils are characterized as deep, well-drained soils with a low permeability and a winter water table within one or two feet of the surface. This soil type is formed from interbedded clay shale, shale, and limestone bedrock.

None of the Site land is utilized for agrarian purposes.

Regional Stratigraphy

The geologic formations that underlie the portion of Allegheny County in which the Site is located are part of the Pennsylvanian System. The Monongahela, Conemaugh, and Allegheny Groups, all part of the Pennsylvanian System, underlie the Site. The Monongahela Group, the uppermost group, includes beds of limestone, variable shales, discontinuous layers of sandstone and coal beds. The base of the Pittsburgh Coal marks the base of the Monongahela Group. Table 3 presents a generalized description of the rock strata beneath the Site.

Some of the important beds in the Monongahela Group are the Uniontown Limestone, Benwood Limestone, Sewickley Sandstone, Fishpot Limestone, Pittsburgh Sandstone, and the Redstone and Pittsburgh Coals. Core borings taken on-site confirm that the bedrock consists of layers of limestone, shale, and sandstone.

Extensive mining of the Pittsburgh Coal seam has occurred to the west and south as well as under the Site. The Pittsburgh Coal seam lies about 200-250 feet below the developed portion of the Site. Most of the Pittsburgh Coal that can be mined has been removed. There are no current coal mining activities in this area.

Structural Geology

The bedrock under the Site declines to the southeast a few feet per mile. The Pittsburgh Coal seam under the Site dips 1% to the southeast.

Hydrogeology

The Site is underlain by the geologic units of the Pennsylvanian Monongahela Group. The Monongahela Group is not an important local aquifer. Well yields from the Monongahela Group range from less than one to 30 gallons per minute. Pump tests performed at the Site in the Sewickley Sandstone Water-Bearing Zone, which is one of the main water-bearing zones in the Monongahela Group at the Site, could not sustain flow rates of one to three gallons per minute.

TABLE 3

GENERALIZED SECTION OF ROCK STRATA BENEATH THE BETTIS ATOMIC POWER LABORATORY

System	Group	Formation	Strata	Remarks
PENNSYLVANIAN	Monongahela	Pittsburgh	Cyclic sequences of shale, limestone, claystone, and coal. Pittsburgh Coal seam is bottom stratum.	Extends from at or near surface down to Pittsburgh Coal. Mined out about 200-250 feet below Bettis.
	Conemaugh	Casselman	Cyclic sequences of sandstone, shale, silty claystone ("red beds"), and thin limestone and coal.	Coal deposits of this group not normally mined. Formation is about 250-300 feet thick; base is near normal level of Monongahela River.
		Glenshaw	Cyclic sequences of sandstone, shale, red beds, and thin limestone and coal; fossiliferous limestone.	Formation is 300 to 380 feet thick.
	Allegheny	Freeport	Upper Freeport Coal seam is top stratum.	Major coal bed, 600 to 630 feet below level of Pittsburgh Coal.
Pennsylvanian System Rocks extend down to about sea level.				

The topographic features of the area, such as high hills cut by major stream valleys, greatly affect the direction and depth of water tables. There may be subregional groundwater regimes where the discharge of the groundwater is to local streams. In cases where the stream channels lie below the water table, some aquifers may discharge on valley slopes.

Based on data obtained through rock coring, monitoring well drilling, geophysical logging, and groundwater elevation monitoring, the groundwater under the Site is present in five different water-bearing zones. The water-bearing areas are referred to as water-bearing zones rather than aquifers because the amounts of water present in these zones are not sufficient to meet the definition of an aquifer as defined by the American Geological Institute. The water-bearing zones in descending order are: Perched, Benwood Limestone, Sewickley Sandstone, Pittsburgh Sandstone, and Pittsburgh Coal. The Pittsburgh Coal Water-Bearing Zone represents the basal groundwater flow at the Site. These water-bearing zones are described in detail in Reference (1).

There are no springs or wells on-site or in the local, hydraulically downgradient areas which are known to be used for drinking water, industrial, or irrigation purposes.

Meteorology

The Site has a humid, continental type of climate modified only slightly by the Atlantic Seaboard and the Great Lakes. Data accumulated by the Site meteorological monitoring system during 2018 indicated that prevailing winds for the Site occurred about 27% of the time from the south-southeast and about 23% of the time from the west-northwest. Wind speeds of greater than five miles per hour (mph) occurred about 68% of the time and less than five mph about 32% of the time. The average monthly temperatures during 2018 ranged from 26 to 74°F. The annual precipitation amounted to approximately 65 inches of water.

ENVIRONMENTAL PROGRAM AND COMPLIANCE

ENVIRONMENTAL PROGRAM

Policy

The Bettis Atomic Power Laboratory (Bettis) is committed to conducting operations and activities in a manner that provides and maintains safe and healthful working conditions, protects the environment, and conserves natural resources. Bettis is committed to environmental excellence through compliance with applicable Federal, State, and local regulations; proactive planning to integrate sound environmental, safety, and health (ESH) principles into every aspect of the work, including hazard identification and risk assessment; and a solid commitment to waste minimization and pollution prevention.

Objectives

The objectives of the Bettis environmental monitoring program are to:

- Demonstrate compliance with regulatory requirements;
- Demonstrate Site operations do not significantly impact the quality of the surrounding environment;
- Confirm the effectiveness of control methods in preventing increases in environmental radioactivity levels;
- Demonstrate that operations within Laboratory facilities have not increased radiation exposure to the general public outside these facilities;
- Provide accurate monitoring results and records of effluent releases to the environment from the Bettis Site; and
- Determine if environmental releases adversely affect the conclusions of the RFI.

Organization

Bettis employs environmental professionals who are responsible for ensuring environmental commitments are fulfilled while also supporting the mission of the NNPP. These environmental professionals work to identify, interpret, and communicate environmental requirements to other Bettis personnel for implementation; assist Bettis organizations in meeting their environmental responsibilities; monitor environmental activities for compliance; interface with regulatory agencies; and complete required regulatory reports.

ENVIRONMENTAL, SAFETY, AND HEALTH MANAGEMENT SYSTEM

The Environmental, Safety, and Health Management System (ESHMS) documents the management processes and systems to perform work in a manner protective of employees, the public, and the environment, while ensuring regulatory compliance. Environmental performance objectives, performance measurements, and commitments are prepared and reviewed annually. The management processes and systems are used to identify, communicate, implement, assess, and update environmental programs.

ENVIRONMENTAL COMPLIANCE

Compliance with environmental regulations is an integral program objective and is essential for successful Site operations. Compliance with environmental regulations is demonstrated by several methods. Federal, State, and local regulatory personnel perform site visits and compliance inspections periodically. During 2018, five site environmental inspections/visits were performed at Bettis by Federal, State, or local agencies. A list of the inspections/visits is shown in Table 4. These inspections/visits did not identify any noncompliant issues in environmental areas. Questions or deficiencies identified during these inspections were immediately addressed or promptly corrected.

TABLE 4

SUMMARY OF ENVIRONMENTAL INSPECTIONS/VISITS BY REGULATORY AGENCIES

Agency(1)	Area Inspected/Visited	Date	Purpose
PADEP	NPDES Permit Program	2/20/2018	NPDES Permit Compliance and Outfall Inspection
ACHD	Operations Center Relocation Project	3/16/2018	Asbestos Abatement Clearance Inspection
PADEP	Permitted Waste Storage Facility, Residual Waste Storage Tanks, Waste Accumulation Areas	6/6/2018	Annual Solid Waste Management Inspection
ACHD	AT-Building Renovation Project	7/16/2018	Asbestos Abatement Clearance Inspection
ACHD	K-Building & CY-Building Process Area	11/5/2018	Asbestos Abatement Clearance Inspection

NOTES:
(1) ACHD – Allegheny County Health Department
PADEP – Pennsylvania Department of Environmental Protection

There were no Notices of Violation, Notices of Deficiencies, Notices of Intent to Sue, or other types of enforcement actions issued to Bettis in 2018. The discussion of the closeout of the Consent Orders for Corrective Measures can be found in the "Corrective Measures Implementation" section of this report. However, in January 2018, there was a release of sanitary sewage to the storm sewer system that discharges through Outfall 001. The release stemmed from a frozen two inch plastic force main that broke after an extended period of extremely cold weather. The PADEP was notified verbally and a follow up written report was submitted to the PADEP. There was no significant impact on human health or the environment from the release. Additionally, in October 2018, non-friable asbestos floor tiles were removed without asbestos work controls in the K-Building. Upon discovery, work was stopped and air monitoring was immediately performed with no airborne asbestos detected. The ACHD was promptly notified of the event.

Compliance is evaluated during internal environmental audits and evaluations performed by elements of the NNPP, including the Laboratory's Site Assessment Organization, the Environmental, Safety and Health organization and other Laboratory personnel (technicians, engineers, and managers).

Compliance with some requirements is demonstrated by effluent and environmental monitoring results. These results are discussed in this report.

Compliance is also demonstrated in many of the environmental reports prepared each year. Approximately 70 environmental related reports were submitted to Federal, State, and local agencies.

Bettis Environmental Permits

The Site has obtained or applied for the applicable environmental permits, which are listed in Table 5.

TABLE 5

ENVIRONMENTAL PERMITS

Operation Permitted	Unit Permitted	Permit Number	Permitting Agency	Expiration Date
Air Emissions	Bettis Site	Synthetic Minor Source Operating Permit 0067d	Allegheny County Health Department	June 22, 2011 (Note 1)
	Bettis Site Asbestos Abatement Operation & Maintenance Plan for Fluor Marine Propulsion, LLC work	PAA-18-0025	Allegheny County Health Department	(Note 2)
	Bettis Site Asbestos Abatement Operation & Maintenance Plan for BWSR, LLC work	PAA-18-0026	Allegheny County Health Department	(Note 2)
	Specific Asbestos Abatement Activities	Various	Allegheny County Health Department	(Note 3)
Water Discharges	Bull Run Monitoring Station Stormwater Outfalls Springwater Intercept System (SIS)	National Pollutant Discharge Elimination System (NPDES) Permit PA0000914	Pennsylvania Department of Environmental Protection	(Note 4)
	Stormwater Discharges Associated with Construction Activity	General NPDES Permit PAG20002041002R	Pennsylvania Department of Environmental Protection	March 22, 2020
	Operation and Maintenance of Springwater Intercept System (SIS)	Water Quality Management Part II Permit 0297202 A-3, T-1	Pennsylvania Department of Environmental Protection	(Note 5)
	Cafeteria Grease Trap	P8502-022-1221	West Mifflin Sanitary Sewer Municipal Authority	December 31, 2021
Hazardous and Mixed Waste Storage	Permitted Waste Storage Facility	Solid Waste Permit PA0890090004	Pennsylvania Department of Environmental Protection	September 13, 2027
Permit for Corrective Action	Various Site Areas and Activities	PA0890090004	Environmental Protection Agency	August 20, 2023

NOTES:
(1) Permit renewal application submitted December 14, 2010. The permit is administratively extended until the ACHD acts on the revised permit renewal application.
(2) Permit is renewed annually.
(3) Permits are obtained on an as needed basis.
(4) Permit renewal application submitted September 28, 2006. A draft NPDES Permit was received from the PADEP on June 29, 2007. A revised permit renewal application was submitted on March 6, 2014. The permit is administratively extended until the PADEP acts on the revised permit renewal application.
(5) Permit is in effect as long as the Springwater Intercept System (SIS) is operational.

Environmental Controls

A description of key environmental control programs is provided below.

Clean Water Act (CWA)

The Federal Clean Water Act and the Pennsylvania Clean Streams Law regulate the chemical components and physical attributes of liquids that Bettis discharges to the surface waters of the Commonwealth of Pennsylvania. Specifically, discharges are authorized through a NPDES Permit, which is administered by the Commonwealth. The NPDES Permit has been renewed several times and covers six outfalls where Laboratory effluent is discharged to surface waters of the Commonwealth. One outfall discharged stormwater, process wastewater, and once-through, non-contact cooling water in 2018. Four outfalls discharge only stormwater runoff. One outfall discharges effluent from the Springwater Intercept System (SIS), which is a groundwater treatment system that is operated in accordance with a 1999 Consent Order with the PADEP. In addition, stormwater runoff from earth disturbance activities is regulated under a separate, General NPDES Permit for stormwater discharges associated with construction activities, and the Allegheny County Conservation District requires a project-specific Erosion and Sedimentation Control Plan for these areas.

The NPDES Permit specifies limits for various chemical constituents and physical attributes in effluents from the Site. Compliance with NPDES Permit limits is demonstrated by periodic samples, which are analyzed for the parameters specified in the NPDES Permit by a laboratory registered in accordance with the Pennsylvania Environmental Laboratory Accreditation Act. A summary of the NPDES Permit sample analysis results is provided in the Liquid Effluents section of the Environmental Monitoring Programs of this report. The results demonstrate compliance with the NPDES Permit.

The NNPP regulates the potential radiological components of liquid discharges to the local surface waters. This authority was provided in Executive Order 12344 dated February 1982, which was codified into law via Public Law 98-525, Title XVI, Section 1634 (50 U.S.C. §2511) and Public Law 106-65, Division C, Title XXXII, Section 3216 (50 U.S.C. §2406). The Program implements a “zero discharge” policy regarding the radiological components of liquid discharges to local surface waters. Compliance is demonstrated by continuous sampling and monthly analyses of discharges that have a potential for radiological constituents. A summary of the sample results is provided in the Liquid Effluents section of the Environmental Monitoring Programs of this report.

Discharges of domestic wastes to the sanitary sewer system are regulated by 40 CFR 403 and the West Mifflin Sanitary Sewer Municipal Authority under Resolution 69-02. Compliance is demonstrated by periodic samples. A summary of the sample results is provided in Table 9. The results demonstrate compliance with the West Mifflin Borough Resolution 69-02.

Clean Air Act (CAA)

The Federal Clean Air Act (CAA), the Pennsylvania Air Pollution Control Act, and the Allegheny County Health Department (ACHD) Air Pollution Control Regulation (Article XXI) regulate non-radiological Laboratory air emissions. The Laboratory’s air operating permit issued by ACHD is designed to regulate emissions based on applicable provisions in Article XXI, National Ambient Air Quality Standards, New Source Performance Standards, National Emissions Standards for Hazardous Air Pollutants (NESHAPs), and other Federal requirements.

The asbestos program at Bettis complies with the requirements of ACHD Article XXI as well as the NESHAPs to minimize the air emissions resulting from asbestos related activities. Personnel monitoring as well as area monitoring is conducted during asbestos removal activities to demonstrate compliance with the asbestos emissions and exposure standards.

Radiological air emissions, except radon gas emissions, are regulated by the EPA under the requirements of NESHAPs (40 CFR 61 Subpart H). Radiological air emissions that could result in a dose to the public that exceeds 1% of the annual dose limit are required to be continuously sampled, and the composite samples are analyzed periodically. At Bettis, all potential radiological air emissions are continuously sampled even though the majority of the emissions do not rise to the regulatory threshold that requires sampling and analysis. Radon gas emissions are controlled by the NNPP. Table 13 of this report provides the radiological air emission monitoring results which demonstrate compliance with the EPA regulations and NNPP requirements.

Waste Management

A waste is any material that is discarded, abandoned, recycled, or inherently waste-like, and includes solids, liquids, semi-solids, and gases. Wastes are evaluated and classified into one or more of the categories discussed in the following sections.

Resource Conservation and Recovery Act (RCRA)

The federal Solid Waste Disposal Act as amended by RCRA and/or the Pennsylvania Solid Waste Management Act regulate the management and disposal of municipal, residual, hazardous and universal waste. The EPA has delegated its authority to the PADEP for RCRA, with the exception of a few specific sections, such as Section 3008(h). Bettis complies with the requirements of a Hazardous Waste Storage Permit issued by PADEP. Representatives of PADEP inspect the Site annually for compliance.

Hazardous wastes are evaluated as a wastewater or nonwastewater and for the presence of underlying hazardous constituents to ensure compliance with the Land Disposal Restrictions.

Specific training is provided to personnel who handle hazardous wastes to ensure that they are knowledgeable of safe handling techniques and emergency response procedures. Hazardous wastes are accumulated in designated staging and storage areas where they are segregated and packaged for shipment. Storage and accumulation areas are inspected periodically to verify that hazardous wastes are properly stored and controlled in accordance with approved procedures. Waste is stored only as necessary to accumulate sufficient volume for economical shipment to a waste disposal vendor.

No hazardous wastes were disposed of on the Site. Approximately 10,750 pounds of hazardous waste were shipped off-site to permitted facilities for final treatment and disposition. Of this amount, approximately 1,290 pounds of the total hazardous wastes disposed resulted from remediation efforts. Written documentation was received from the disposal facilities verifying that the waste was received and handled in accordance with applicable requirements. The Site chose vendors with treatment and disposal methods that would reduce long-term concerns and threats to the environment.

Bettis currently recycles or reclaims (e.g., by managing as universal waste) the following items that would otherwise be disposed of as hazardous waste: spent batteries (e.g., nickel cadmium, lithium ion, lead-acid), bulbs (e.g., fluorescent, incandescent), and mercury containing equipment (e.g., thermostats,

mercury switches). In 2018, approximately 18,700 pounds of spent batteries and 2,200 pounds of spent bulbs were sent off-site for recycling or reclamation.

Federal Facility Compliance Act (FFCA)

Mixed waste is waste that meets the criteria of both hazardous and radioactive waste. Under the FFCA, mixed wastes are regulated by State and Federal hazardous waste regulations in accordance with a Mixed Waste Management Plan which has been agreed to by the PADEP, and by the NNPP for radiological constituents.

The amount of mixed waste generated is minimized through the use of detailed work procedures and worker training. Mixed wastes are accumulated in designated storage areas where they are packaged for storage for eventual treatment in accordance with an EPA-approved Site Treatment Plan, which was developed under the FFCA.

Mixed wastes have never been disposed of on-site. In 2018, there were three shipments totaling approximately 3.1 cubic meters of various mixed wastes sent to treatment and disposal facilities.

Municipal and Residual Waste

The State of Pennsylvania divides non-hazardous solid waste into two major categories, residual waste and municipal waste. Residual waste is primarily from industrial operations and municipal waste is from residential, municipal, commercial or institutional establishments. Municipal waste includes industrial lunchroom or office waste and construction and demolition debris. In 2018, approximately 627 tons of municipal and 20 tons of residual waste were shipped off-site for disposal.

PADEP regulates medical waste in Title 25 of the PA Code, Chapters 271, 273, and 284. PADEP defines infectious waste (regulated medical waste) as “municipal and residual waste which is generated in the diagnosis, treatment, immunization, … of human beings…”. The Bettis Medical Department is responsible for handling, storage, and off-site disposal of the wastes generated at Bettis. These wastes are disposed of by incineration or sterilization at state-licensed facilities. In CY 2018, Bettis sent approximately 260 pounds of regulated medical waste off-site for disposal.

Asbestos containing waste is managed in accordance with regulations issued by Federal, State and local agencies. Compliance with the asbestos regulations is managed through permits and notifications as well as engineering practices to protect human health and the environment from asbestos exposure. Asbestos waste is packaged, labeled and disposed according to the applicable regulations.

Radioactive Waste

Radioactive wastes are regulated under the authority of the NNPP. The volume of waste containing radioactivity is minimized through the use of detailed work procedures and worker training to limit the amount of material that contacts radioactivity during work in radioactive areas or on radioactive systems and components.

Detailed procedures are used during generation, handling, packaging, and transportation of radioactive waste material. Radioactive wastes shipped off-site are packaged in accordance with applicable U. S. DOE disposal site criteria and the U.S. Department of Transportation regulations in Reference (2). All other radioactive liquid wastes are solidified prior to shipment. Internal reviews are made prior to each

shipment to ensure that the radioactive material is properly identified, surveyed, and packaged in accordance with Federal and disposal site requirements.

During 2018, approximately 1,442 cubic meters of radioactive waste were shipped from the Bettis Site for disposal.

Waste Minimization, Pollution Prevention, and Recycling Programs

The Bettis waste minimization and pollution prevention program promotes pollution prevention and waste minimization by encouraging employees to reduce the initial use of hazardous materials, energy, water, and other resources while protecting existing resources through conservation and more efficient use. The program focuses mainly on process efficiency improvements, source reduction, inventory control, preventive maintenance, improved housekeeping, recycling, and increasing employee awareness of and participation in pollution prevention. The goal of the program is to minimize the quantity and toxicity of waste generated at its source and, if waste is generated, to ensure that the treatment and disposal method used minimizes the present and future threat to people and the environment. The program consists of the following elements:

- Control of chemical acquisitions, including type and quantity;
- Maximized use of on-hand chemicals;
- Minimized production of process wastes (Source Reduction); and
- Process evaluation/modification.

Bettis ensures pollution prevention strategies are met by reviewing chemical purchases and major construction projects to incorporate source reduction strategies for environmentally hazardous substances.

Consistent with the ESHMS, the Bettis Atomic Power Laboratory has established and implemented a sustainable acquisition program. Progress in sustainable acquisition is reported annually to the DOE via the DOE Sustainability Dashboard. Sustainable acquisition maximizes the amounts of material procured that contain recycled material. Environmentally preferable items reported in the Bettis program include but are not limited to: paper and paper products; vehicular (e.g., engine coolants, oils), construction (e.g., insulation, carpet, concrete, paint) and transportation products (e.g., traffic barricades, traffic cones); park and recreation products; landscaping products; non-paper office products (e.g., binders, toner cartridges, office furniture); and miscellaneous products (e.g., pallets, sorbents, and industrial drums).

Bettis also maintains an extensive recycling program which includes office paper, cardboard, newspapers, telephone books, printer cartridges, scrap metal, batteries, scrap lead, cooking oil, aluminum cans, asphalt, tires, oil, light bulbs, circuit boards, computer equipment, magnetic media, precious metals, cement and wood. Bettis recycled approximately 77% of its municipal waste stream in 2018 compared to 75% in 2017. Asphalt continues to represent a substantial portion of recyclable materials generated by Bettis.

Toxic Substance Control Act (TSCA)

Polychlorinated biphenyls (PCBs) are regulated by the Toxic Substances Control Act under 40 CFR Part 761. PCBs were historically used as a dielectric fluid in electrical equipment, such as transformers and

capacitors. PCBs were also added to certain surface coatings and other non-liquid materials due to their heat and chemical resistance. Bettis has identified PCBs in materials such as small electrical transformers, fluorescent light ballasts, applied dried paints, lubricants/machine oils, and electrical cable insulation. Bettis has removed all large PCB transformers from the site and continues to remove and replace PCB fluorescent light ballasts, where practical. Bettis employs strict controls for removal, storage and disposal of its remaining PCB containing materials.

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

The Comprehensive Environmental Response, Compensation, and Liability Act, commonly referred to as CERCLA or Superfund, was enacted to address the cleanup of hazardous substances, primarily at abandoned industrial sites and disposal facilities. In 1988, a *Preliminary Assessment and Site Inspection (PA/SI) Report* was completed for the Site in accordance with the requirements of Section 120 of CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986. This report included a Hazardous Ranking System (HRS) assessment of the areas at Bettis where chemical and radiological residues have been found in the environment and concluded that the risks posed by these residues were well below that required for inclusion of the Site on the National Priorities List for subsequent remediation.

This report was submitted to the EPA and PADEP for review. The EPA reviewed the submittal, revised the conservative Bettis HRS score of 16.5 to zero, and concluded that no further action or remediation was required under CERCLA.

In 1990, the Pittsburgh Naval Reactors Office (PNR), now known as NRLFO, and the EPA signed a Consent Order in accordance with Section 3008(h) of RCRA. The mutual objectives of EPA and PNR were to investigate fully the nature and extent of past releases of chemically hazardous constituents at Bettis and to identify and evaluate corrective actions to prevent or mitigate the migration of these constituents. The investigation was completed and the Consent Order was terminated in 1997. Subsequently, Bettis implemented the majority of the EPA selected corrective measures.

Bettis implemented the last three outstanding corrective measures in 2001 in accordance with a Corrective Measures Implementation Order with the EPA.

Bettis completed the final corrective action of the CMIO, the enhanced soil vapor extraction at the Bettis Landfill, in September 2012. Some corrective actions within the CMIO require the continuation of environmental monitoring and maintaining administrative controls. On August 21, 2013, the EPA issued a Corrective Action Permit that maintains these requirements.

On September 11, 2013, the EPA concluded that all the terms of the 2001 CMIO had been satisfied and issued a letter terminating the agreement between the EPA and the Bettis Atomic Power Laboratory. Refer to the Sections on “Assessment of Risk from Chemical Residues” and “Corrective Measures Implementation” for additional details on environmental remediation.

Emergency Planning and Community Right-to-Know Act (EPCRA)

Sections 311, 312, and 313 of the Superfund Amendments and Reauthorization Act (SARA), Title III, also known as the Emergency Planning and Community Right-to-Know Act (EPCRA) require periodic reporting of information on extremely hazardous substances and toxic chemicals used or stored on-site,

including persistent bio-accumulative toxic chemicals, to the State Emergency Response Commission, the local Emergency Planning Committee, and local fire departments.

Compliance with these regulations is accomplished through the Site's Chemical Procurement and Chemical Inventory Programs. Chemicals subject to the above regulations are inventoried quarterly and the appropriate reports are submitted to the regulatory agencies as required.

Bettis has also submitted the Planning Notification and the Extremely Hazardous Substance (EHS) Release Notification as required by Sections 302-303 and 304, respectively, of the EPCRA.

TABLE 6

Status of Bettis Site EPCRA Reporting

EPCRA Section	Description of Reporting	Status
EPCRA Sec. 302-303	Planning Notification	Notification completed for calendar year
EPCRA Sec. 304	Extremely Hazardous Substance Release Notification	No reportable releases
EPCRA Sec. 311-312	Safety Data Sheet/Chemical Inventory	Notification completed for calendar year
EPCRA Sec. 313	Toxic Release Inventory Reporting	Reporting not required due to insufficient use on site

Federal Insecticide, Fungicide, and Rodenticide Act

Pesticides, which include herbicides, insecticides, biocides, and rodenticides, are regulated by the EPA under the Federal Insecticide, Fungicide, and Rodenticide Act and by the Pennsylvania Department of Agriculture (PADA). The procurement and use of pesticides are rigidly controlled to ensure the EPA and PADA requirements are met.

National Environmental Policy Act (NEPA)

Significant construction, renovation, and demolition activities are reviewed for their impact on the environment under the National Environmental Policy Act (NEPA) requirements as provided by the DOE. Other physical construction projects or capital equipment that have the potential for creating new emissions to the environment also receive a NEPA evaluation. Categorical Exclusions and all NEPA documentation for NNPP Sites, including the Bettis Atomic Power Laboratory, are available online on the DOE NEPA website located at www.energy.gov/nepa/nepa-documents.

ENVIRONMENTAL MONITORING PROGRAMS

The major elements of the Site's radiological and nonradiological environmental monitoring programs are summarized in Tables 1 and 2. The various programs and the monitoring results are discussed in this section.

A. LIQUID EFFLUENTS

The purpose of the liquid effluent monitoring programs is to determine the effectiveness of control methods and to measure constituent concentrations in effluents for comparison with applicable standards and natural background levels. In addition to monitoring liquid effluents from the Site, samples of precipitation and influent city water are monitored and used for background comparisons.

Sources

The principal sources of liquid effluents to the storm sewer system included noncontact cooling water, stormwater runoff, and process wastewater. Total effluent flow through the Bull Run Monitoring Station is measured in accordance with the NPDES Permit; in 2018, the total flow was approximately 43,500,000 gallons. This comprises most of the flow in the Bull Run Stream. Stormwater runoff via Stormwater Outfalls 003, 005, 006 and 008, and treated groundwater via Outfall 007 was also discharged in accordance with the Site's NPDES Permit. Approximately 19,100,000 gallons of treated groundwater were discharged from the SIS through Outfall 007. The SIS consists of a groundwater collection system and air strippers that are used to remove VOCs, primarily PCE, from the collected groundwater prior to discharge. In addition, stormwater runoff from construction activities was also discharged in accordance with a General NPDES Permit obtained specifically for the discharge. Figure 3 shows the locations of these outfalls.

Water used for sanitary and cleaning purposes was discharged via the sanitary sewer system to the West Mifflin Sanitary Sewer Municipal Authority, Thompson Run Sewage Treatment Plant, which discharges treated effluent to the Thompson Run Stream. In addition, approximately 223,100 gallons of processed groundwater and water generated from sampling efforts (less than 50 gallons) were discharged to the Thompson Run Sewage Treatment Plant. This water contained traces of VOCs primarily PCE, which were within allowable release limits to the treatment plant. The Borough of West Mifflin, the U.S. EPA, and the PADEP were previously notified of the discharges as required by applicable regulations.

Liquid Monitoring

The samples and analyses specified below constitute the minimum samples and analyses conducted at the Site during 2018.

Radiological: Representative water samples of storm sewer liquid effluents were collected at the Bull Run Monitoring Station and Outfall 008 (annually) shown on Figure 3. Monthly, the composite samples were collected and analyzed for gross alpha and gross beta radioactivity. Quarterly, composites of the monthly samples were analyzed for Sr-90 and gamma-emitters. Influent city water and precipitation samples were analyzed similarly to the liquid effluent samples. Annually, water samples are collected from the Bull Run Stream at the Site boundary (BR5, Figure 3) and Outfall 008 and analyzed for gross alpha, gross beta, Sr-90, and gamma emitters. In addition, the water sample from BR5 is analyzed for isotopic uranium. Samples of processed groundwater were analyzed for gross alpha and gross beta

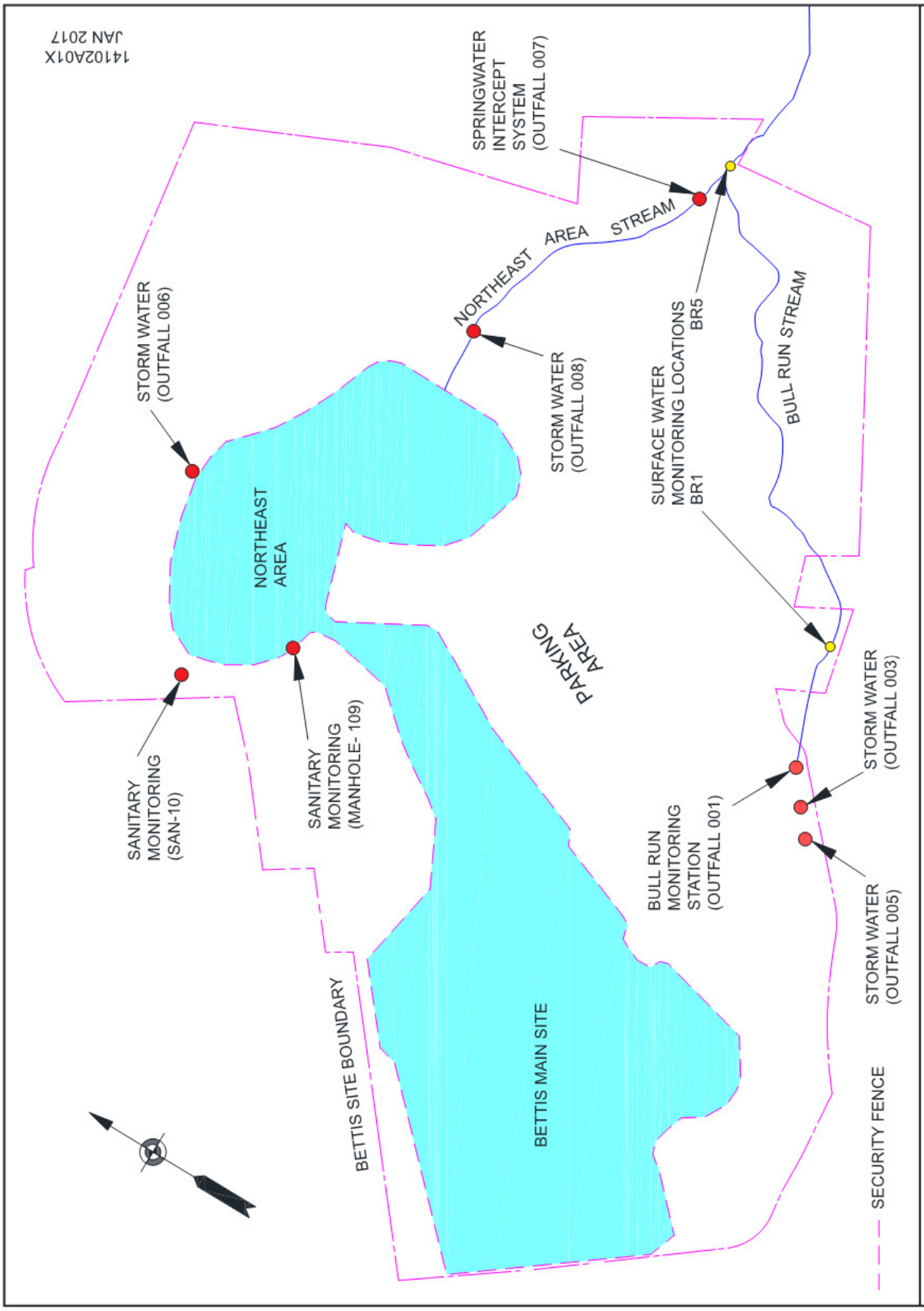

FIGURE 3 LIQUID EFFLUENT OUTFALL AND MONITORING LOCATIONS

radioactivity prior to release of the processed water to the sanitary sewer to ensure that the processed water did not contain any detectable radioactivity. The DLCs were below the radioactivity levels allowed by the EPA for drinking water in 40 CFR 141 (Reference (3)). Samples of sanitary effluent were collected monthly at the outfall of the main site area, location Manhole-109 (MH-109), shown on Figure 3. These samples were analyzed for gross alpha and gross beta radioactivity.

Quarterly, a composite of the monthly samples from MH-109 was analyzed for Sr-90 and gamma emitters. Semiannually, samples of sanitary effluent were collected at location SAN-10 which includes sanitary effluent for the entire Site as shown on Figure 3. These samples were analyzed for gross alpha and gross beta radioactivity.

Nonradiological: Semimonthly, samples of storm sewer effluents discharged through the Bull Run Monitoring Station were collected and analyzed, in accordance with the NPDES Permit, for oil and grease, pH, suspended solids and temperature and also for dissolved oxygen, and fecal coliform bacteria. Semiannually, samples were collected and analyzed for alkalinity, aluminum, ammonia, chloride, hardness, iron (dissolved), iron (total), osmotic pressure, and total dissolved solids. Annually, samples were collected and analyzed for antimony, arsenic, base neutral/acids, beryllium, cadmium, chromium (hexavalent), chromium (total), copper, cyanide (free), lead, mercury, nickel, pesticides, PCBs, selenium, silver, thallium, VOCs, and zinc.

Semimonthly, samples of effluent from the SIS were collected at Outfall 007 and analyzed for iron (dissolved), pH, suspended solids, PCE, trichloroethylene (TCE), and DCE. These analyses are required by the Site's NPDES Permit.

Samples of the influent municipal water supply, which comprised a significant portion of the Site's liquid effluents, were collected at the same frequencies and analyzed for the same parameters described above for the Bull Run effluent.

Semiannually, samples of sanitary effluent were collected at location SAN-10 which includes sanitary effluent for the entire Site. These samples were analyzed for biochemical oxygen demand, chloride, dissolved oxygen, hardness, oil and grease, pH, suspended solids, and temperature. Annually, samples of sanitary effluent were collected and analyzed for mercury and silver.

Samples of Bull Run Stream were collected from two locations, BR1 and BR5 shown on Figure 3, and analyzed for VOCs.

Liquid Analyses

Radiological: Liquid samples (liquid effluent, city water, precipitation, sanitary effluent, groundwater, etc.) were prepared for gross alpha and beta analysis by evaporation of approximately 200 ml of liquid. The alpha and beta radioactivity of the samples were measured using a low background proportional counter. Typical DLCs for alpha and beta radioactivity for 200 ml samples were 2.0×10^{-9} µCi/ml and 3.0×10^{-9} µCi/ml, respectively.

Gamma spectrometry was also performed quarterly on composites of monthly samples to identify gamma-emitting radionuclides using a high purity germanium detector and a multichannel analyzer. Typical DLCs for Cs-137 and cobalt-60 (Co-60) in a 1000 ml sample of these composites ranged from 3.0×10^{-9} to 7.0×10^{-9} µCi/ml.

Sr-90 analyses were performed on selected composites of monthly samples using a standard strontium radiochemical procedure. A typical DLC achieved for Sr-90 was 5.0×10^{-10} µCi/ml for a 1000 ml sample.

Nonradiological: Analyses of influent, effluent, and surface water samples were performed using test methods described in References (4), (5), or other EPA-approved methods.

Liquid Monitoring Results and Conclusions

Radiological: The results of the monthly analyses for alpha radioactivity in the Site's storm sewer effluents showed that the levels were below the DLC and were consistent with background alpha radioactivity levels measured in the city water influent and precipitation. None of the 12 alpha radioactivity measurements of the effluents exceeded the limit of Reference (6) for alpha radioactivity, based on thorium-232 (Th-232), in water in uncontrolled areas.

The results of the monthly analyses for beta radioactivity in the Site's storm sewer effluents showed that the average beta radioactivity levels were consistent with the levels measured in the city water influent and precipitation. The gross beta radioactivity results for a number of surface water samples collected during the winter months were slightly above 1.0×10^{-8} µCi/ml due to the presence of natural potassium-40 (K-40) activity found in water samples when winter de-icing materials are used. The gross beta radioactivity results were subsequently adjusted to account for the contribution of the K-40 found in storm sewer samples. However, even prior to the adjustment, none of the 12 beta radioactivity measurements of the effluents exceeded the limit of Reference (6) for beta radioactivity, based on Sr-90, in water in uncontrolled areas.

Table 7 presents the quarterly composite sample results for the Site's storm sewer effluents at the Bull Run Monitoring Station and Outfall 008, and for precipitation and city water samples. During 2018, there were no occasions when the gross radioactivity analyses result of the sanitary effluent was elevated relative to its local investigation level. The alpha and beta radioactivity levels in processed groundwater released to the sanitary sewer were less than the DLC of 3.0×10^{-9} µCi/ml. This level is below the level allowed by the EPA in drinking water and is typical of natural levels of radioactivity.

The gross alpha, gross beta, and Sr-90 radioactivity levels in the sample of Bull Run Stream at location BR5 (Figure 3) were at or below DLCs. The natural uranium concentrations were: uranium-234 (U-234), 0.638×10^{-9} µCi/ml; uranium-235 (U-235), $<0.0450 \times 10^{-9}$ µCi/ml; and uranium-238 (U-238), 0.677×10^{-9} µCi/ml. These results are consistent with natural background concentrations for uranium in surface water.

Based on the above, the control methods at the Site were effective in ensuring that the water discharged from the Site was of sufficiently high quality to preclude an adverse impact on the environment or downstream water quality. Site-generated radioactivity was not released to the Site's effluent streams or sanitary sewers.

Nonradiological: A summary of sample analysis results for effluent water from the Site are presented in Tables 8, 9, and 10. Since a major portion of the Site's process wastewater effluent is noncontact cooling water, the quality of the effluent is significantly influenced by the quality of the influent city water. Therefore, the influent city water was sampled for the same parameters as the effluent. Table 8 provides the analysis results for the parameters that are required to be sampled by the Site's NPDES Permit. Table 8 also identifies the discharge limits for these parameters as established in the NPDES Permit. Tables 9 and 10 provide the analysis results for various parameters that provide an overall indication of general water quality. Tables 9 and 10 also list the guidelines for general water quality that have been derived from guidelines provided by the PADEP in Reference (7). These guidelines are not effluent limits, but can be compared against the analysis results to provide an indication of the quality of the effluent from the Site.

The results in Table 8 show that the samples collected in accordance with the Site's NPDES Permit for the Site's outfalls were within the established discharge limits.

TABLE 7

LIQUID INFLUENT AND EFFLUENT RADIOACTIVITY RESULTS(1)

Units: 10^{-9} µCi/ml

Sample Location	Activity Analysis	First Quarter	Second Quarter	Third Quarter	Fourth Quarter
Bull Run Monitoring Station Effluent	Strontium-90	0.118 ± 0.111	<0.0838	0.0929 ± 0.0876	0.132 ± 0.118
Outfall 008(2)		<0.330			
City Water		<0.0938	<0.0862	<0.0886	<0.0985
Precipitation		<0.0898	<0.0979	<0.0891	<0.0849
Bull Run Monitoring Station Effluent	Cesium-137	<7.48	<7.49	<5.48	<6.59
Outfall 008(2)		<6.12			
City Water		<7.02	<7.28	<5.14	<7.47
Precipitation		<6.76	<5.85	<5.54	<7.27
Bull Run Monitoring Station Effluent	Cobalt-60	<6.26	<5.82	<7.17	<6.27
Outfall 008(2)		<6.93			
City Water		<5.58	<5.90	<6.18	<6.20
Precipitation		<6.66	<5.95	<6.64	<5.98

NOTES:
(1) A "<" signifies the result was below the DLC, with the DLC being the reported value. DLC values vary slightly due to the sample size, the chemical recovery yield, count time, instrument backgrounds, and the presence of dissolved materials.
(2) Annual sample.

TABLE 8

SUMMARY OF NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES) PERMIT SAMPLE ANALYSES RESULTS(1)

Parameter	Units	Limit	Outfall 001	Outfall 007
			Range	Range(2)
Dissolved Iron	mg/l	7.0 Max.		<0.050 – 0.120
Oil and Grease	mg/l	15 Avg. 30 Max.	<5 – <6 <5 – 6	
pH	Units	6.0 – 9.0	7.7 – 8.5	7.6 – 8.1
Suspended Solids	mg/l	25 Avg. 50 Max.	0.8 – <9.8 <1.0 – 19	
Suspended Solids	mg/l	30 Avg. 75 Max.		<0.6 – <2.4 0.6 – 4.3
Temperature	°F	110 Max.	40 – 75	
Tetrachloroethylene	mg/l	0.0022 Avg. 0.0055 Max.		<0.001 <0.001
Trichloroethylene	mg/l	0.005 Avg. 0.0125 Max.		<0.001 <0.001
trans- 1,2-dichloroethylene	mg/l	0.005 Avg. 0.0125 Max.		<0.001 <0.001

NOTES:
(1) Oil and grease, pH, suspended solids, and temperature samples are required to be collected semimonthly from Outfall 001. Dissolved iron, pH, suspended solids, tetrachloroethylene, trichloroethylene, and trans-1,2-dichloroethylene samples are required to be collected semimonthly from Outfall 007.
(2) For analysis results that do not change for multiple samples, only one sample analysis result is provided.

The general water quality results in Tables 9 and 10 show that all of the non-regulated parameter analysis results were within the water quality guidelines.

Results of VOC water samples collected from the Bull Run Stream at locations BR1 and BR5 (Figure 3, Table 12) were less than 0.007 mg/l for the chemical constituents of concern (tetrachloroethylene, trichloroethylene and 1,2-dichloroethylene).

TABLE 9
SUMMARY OF SEMIMONTHLY AND SEMIANNUAL EFFLUENT WATER QUALITY RESULTS

Parameter	Units	Guideline[1]	Outfall 001	Sanitary Effluent
			Range[3]	Range[3]
Alkalinity	mg/l as $CaCO_3$	>20	130	
Aluminum	mg/l		0.060 – 0.220	
Ammonia	mg/l	1.84	<0.10 – 0.62	
Biochemical Oxygen Demand	mg/l	350		71 – 170
Chloride	mg/l		150 – 550	77 – 340
Fecal Coliform[2]	colonies/ 100 ml		8 – 381	
Hardness	mg/l		130 – 190	150 – 200
Iron, Dissolved	mg/l		<0.050	
Iron, Total	mg/l	1.5	0.097 – 0.200	
Oil and Grease	mg/l	200		<50 - 58
Osmotic Pressure	mosm/ kg	50	<20 – 34	
Oxygen, Dissolved	mg/l	>4.0	7.2 – 16.1	6.0 – 7.4
pH	Units	5.0 – 11.0		8.7
Solids, Dissolved	mg/l		440 – 1200	
Solids, Suspended	mg/l	350		9.3 – 49
Temperature	°F	150		65 – 67

NOTES:
(1) Guidelines for general water quality parameters are based on the guidelines for warm water fishes as identified by the PADEP in Pennsylvania Code, Title 25, Chapter 93, Water Quality Standards. The guidelines noted are for Outfall 001 and do not apply to influent city water or sanitary effluent. Applicable sanitary effluent guidelines are based on West Mifflin Borough Resolution 69-02.
(2) The fecal coliform value is the geometric mean of five consecutive samples.
(3) For analysis results that do not change for multiple samples, only one sample analysis result is provided.

The maximum fecal coliform levels in Outfall 001 were elevated compared to normally expected levels. An investigation of the possible sources of the fecal coliforms indicated that the onsite sanitary sewer lines are not the cause for the presence of the fecal coliforms. The elevated levels occurred when samples were collected during or shortly after precipitation events. A review of the EPA Handbook for Urban Runoff Pollution Prevention and Control Planning indicates that the levels of fecal coliforms detected in Outfall 001 is consistent with those found in typical stormwater runoff for urban areas such as the Bettis site.

Based on the above, the control methods at the Site were effective in ensuring that the water discharged from the Site was of sufficiently high quality to preclude any adverse impact on the environment or downstream water quality.

TABLE 10

ANNUAL EFFLUENT WATER QUALITY RESULTS

Parameter	Units	Guideline[1]	Outfall 001	Sanitary Effluent
Antimony	mg/l	1.100	<0.002	
Arsenic	mg/l	0.340	0.0018	
Base Neutrals/Acids	mg/l	See footnote (2)	<PQL [2][3]	
Beryllium	mg/l		<0.001	
Cadmium	mg/l	0.018	<0.001	
Chromium, Hexavalent	mg/l	0.016	<0.010	
Chromium, Total	mg/l		<0.002	
Copper	mg/l	0.044	0.015	
Cyanide, Free	mg/l	0.022	0.0032	
Lead	mg/l	0.382	0.001	
Mercury	mg/l	0.002	<0.00020	0.00020[1]
Nickel	mg/l	1.31	<0.001	
Pesticides Dieldrin Endrin aldehyde	µg/l	See footnote (2) 0.24 --[4]	<PQL [2][3] 0.0068 0.0012	
Polychlorinated Biphenyls (PCBs)	mg/l		<PQL [2][3]	
Selenium	mg/l		<0.005	
Silver	mg/l	0.033	<0.001	<0.001[1]
Thallium	mg/l	0.065	<0.001	
Volatile Organic Compounds	mg/l	See footnote (2)	<PQL [2][3]	
Zinc	mg/l	0.335	0.160	

NOTES:

(1) The guideline is the maximum concentration guideline based on the fish and aquatic life criteria provided by the Pennsylvania Department of Environmental Protection in Pennsylvania Code, Title 25, Chapter 93, Water Quality Criteria for Toxic Substances. The guidelines noted are for Outfall 001 and do not apply to sanitary effluent. Applicable sanitary effluent guidelines are 0.09 mg/l for mercury and 0.7 mg/l for silver as provided in West Mifflin Resolution 69-02. A hardness value of 336 mg/l was used to calculate several guidelines.

(2) A complete listing of the compounds analyzed along with the associated guidelines is identified in Chapter 93, Table 5 of the Water Quality Criteria for Toxic Substances. Analysis results for each compound analyzed were less than the practical quantitation limit for the parameter unless otherwise specified.

(3) PQL is the practical quantitation limit. Analysis results for each compound analyzed were less than the PQL for the parameter unless otherwise specified.

(4) No specific guideline available.

B. GROUNDWATER

The purpose of the groundwater monitoring programs is to determine the impact of operations on the groundwater. The nonradiological monitoring program is also performed to monitor for the migration of chemical residues in groundwater.

Sources

The primary source of radioactivity and chemical constituents in the Site's groundwater is from operations conducted in the 1950s and 1960s. During that time, small amounts of radioactivity were released from a few isolated locations on-site as a result of minor breaches in containers and underground pipes containing radioactive materials. Since that time, vigorous efforts to prevent recurrence of these problems have been successful, and much of the soil containing residual radioactivity has been removed. However, there remain some areas of soil within the Site confines that contain small amounts of radioactivity from past Site operations. Monitoring is conducted to detect any influence of this activity on water quality.

The chemical constituents originated from infrequent spills or the past practice of on-site disposal of small amounts of spent solvents, typically degreasing agents such as PCE from Site operations. It is also possible that solvent disposal by prior tenants when the Site was an airfield may have contributed to the groundwater contamination. Since the early 1970s, these materials have been disposed of off-site.

Groundwater Monitoring

The samples and analyses specified below constitute the minimum samples and analyses conducted at the Site during 2018. The existing well locations and on-site springs are shown on Figure 4. The wells monitor five water-bearing zones under the Site down to and including the Pittsburgh Coal Water-Bearing Zone. These water-bearing zones, which are illustrated and discussed in detail in the Final RFI, Reference (1), are listed below in order of increasing depth: Perched, Benwood Limestone, Sewickley Sandstone, Pittsburgh Sandstone, and Pittsburgh Coal. The on-site springs and seeps are surface discharge points for water predominantly from the Benwood or Sewickley Water-Bearing Zones.

Radiological: Groundwater samples from on-site and off-site springs and a discharge point for the abandoned Pittsburgh Coal Mine under the site are collected at least annually. Annual groundwater samples from wells were collected and analyzed for gross alpha, gross beta, and gamma-emitters. In addition, water from approximately one-third of the wells in the monitoring program was analyzed for Sr-90 and uranium isotopes. The monitoring program is set up to ensure that all wells in the program are analyzed for Sr-90 and uranium isotopes in a given three year period.

Nonradiological: Groundwater samples are collected from select wells at least annually and analyzed for VOCs.

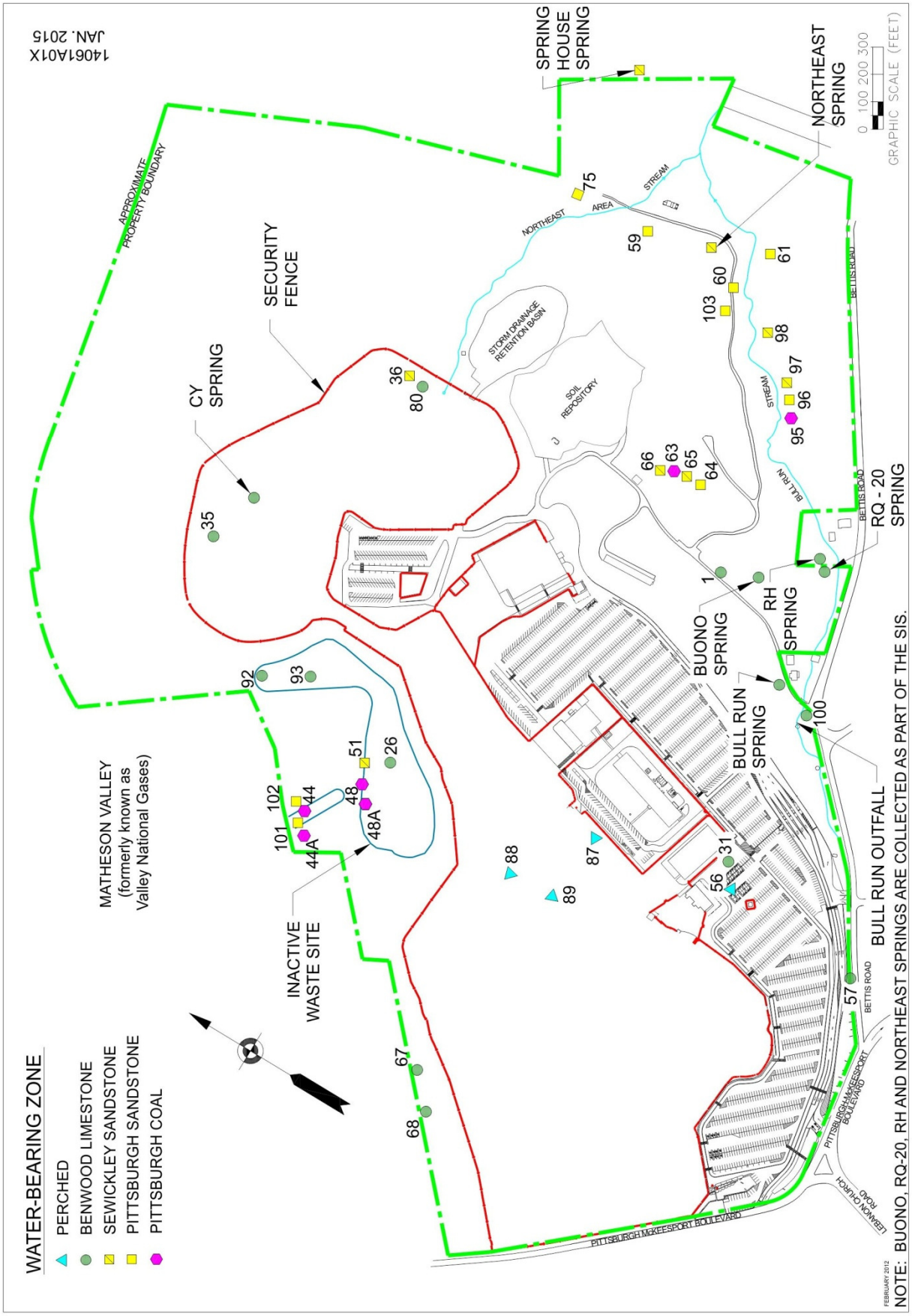

FIGURE 4 LOCATIONS OF WELLS AND SPRINGS

Groundwater Analyses

Radiological: Groundwater analysis methods are discussed under Liquid Analyses in Section A.

Nonradiological: Groundwater samples were analyzed using test methods described in Reference (5).

Groundwater Monitoring Results and Conclusions

Radiological: Table 11 presents the groundwater sample radioactivity data for 2018.

The radioactivity data for the Perched Water-Bearing Zone are consistent with previous results or natural levels of radioactivity in groundwater in this area, with the exception of Sr-90 detected in Wells 87, 88, and 89, located near the Materials Evaluation Laboratory (MEL). Wells 87, 88, and 89 were installed to monitor for migration of residual radioactivity from under the MEL. The highest Sr-90 concentration observed in these wells, 4.35×10^{-9} µCi/ml in Well 89, is less than 1% of the limit of Reference (6) for Sr-90 in water in unrestricted areas. These wells monitoring the Perched Water-Bearing Zone will continue to be sampled annually for radioactivity. The 2018 data show that Bettis operations have not significantly affected the overall levels of radioactivity in the Perched Water-Bearing Zone.

The radioactivity data for the Benwood Water-Bearing Zone wells and springs that were sampled in 2018 are consistent with previous results or typical natural levels of radioactivity. There are eleven wells in this zone. Bettis operations have not affected the natural levels of radioactivity in the Benwood Water-Bearing Zone.

The radioactivity data for the Sewickley Sandstone Water-Bearing Zone wells and springs that were sampled in 2018 are consistent with previous results or natural levels of radioactivity. There are six wells in the Sewickley Sandstone Water-Bearing Zone, of which at least three will be sampled annually. Bettis operations have not affected the natural levels of radioactivity in the Sewickley Sandstone Water-Bearing Zone.

The radioactivity data for the Pittsburgh Sandstone Water-Bearing Zone wells that were sampled in 2018 are consistent with natural background levels. There are nine wells in the Pittsburgh Sandstone Water-Bearing Zone. Bettis operations have not affected the natural levels of radioactivity in the Pittsburgh Sandstone Water-Bearing Zone.

The radioactivity data for the Pittsburgh Coal Water-Bearing Zone wells that were sampled in 2018 are consistent with natural levels of radioactivity. The six wells in this zone will be sampled annually. Bettis operations have not affected the natural levels of radioactivity in the Pittsburgh Coal Water-Bearing Zone.

Historically, some of the water in the abandoned Pittsburgh Coal Mine under the Site discharged into the Borough of Dravosburg combined sanitary/storm sewer system. During 1998, the combined sewer system was modified so the discharge from the abandoned mine no longer enters the sanitary sewer system. Samples of this discharge were analyzed for radioactivity, and the results are presented in Table 11 as sample point DM176. The results are consistent with natural levels of radioactivity and demonstrate that Site operations have not affected the natural levels of radioactivity in this water.

In summary, the radiological operations at the Laboratory did not impact the groundwater in 2018. Overall, Site operations have not significantly affected the natural radioactivity in the water-bearing zones under the Site.

Nonradiological: The results of the analyses of groundwater for the chemical constituents of concern are presented in Table 12. Previous environmental monitoring results have shown that the contaminants of concern in Site groundwater are VOCs, primarily PCE and its degradation products, TCE and DCE. Groundwater samples analyzed during the RFI showed the following average total VOC level in the water-bearing zones: Perched, 0.1 mg/l; Benwood Limestone, 1.3 mg/l; Sewickley Sandstone, 5.9 mg/l; and Pittsburgh Sandstone, 0.065 mg/l. The 2018 groundwater monitoring results for VOCs are consistent with previous results. It should be noted that although the VOC concentrations in Well 65 are considerably higher than those in other on-site wells, these levels are consistent with those detected in this well during the RFI and in subsequent samples and are thus typical for this well. More importantly, downgradient monitoring of the Sewickley Sandstone and the deeper Pittsburgh Sandstone has not detected changes, indicating that the conclusions of the RFI remain valid.

The 2018 groundwater monitoring results are consistent with previous results and do not show any changes in the migration pattern of chemical residues in the groundwater, indicating that the conclusions of the RFI remain valid.

TABLE 11

GROUNDWATER RADIOACTIVITY RESULTS

Units: 10^{-9} µCi/ml

Sample Location	Radionuclides[1]							
	Gross Alpha	Gross Beta	Sr-90	Cs-137	Co-60	U-233/-234[2]	U-235	U-238
Perched Water-Bearing Zone								
Well 56[4]	<82.5	<32.9	<0.328	<5.92	<6.43	0.128 ± 0.113	<0.0596	0.154 ± 0.123
Well 87[4]	<13.6	11.2 ± 6.36	0.979 ± 0.404	<6.89	<6.76			
Well 88	<7.30	<6.07	<0.377	<7.05	<7.17			
Well 89[4]	<44.4	<30.7	4.35 ± 0.725	<7.30	<5.24			
Benwood Limestone Water-Bearing Zone								
Well 26	<8.86	7.98 ± 8.13		<7.48	<6.47	2.02 ± 0.405	<0.0443	1.54 ± 0.350
Well 31[4]	<40.4	<30.5		<7.46	<5.90			
Well 35	<5.16	<5.97		<7.03	<5.64			
Well 57[4]	<30.3	<13.0	<0.440	<7.41	<5.50	0.171 ± 0.119	<0.0496	0.128 ± 0.103
Well 68	<7.52	<6.08		<7.03	<7.23			
Well 80	<6.89	<6.05		<7.46	<5.89			
Well 92	7.26 ± 8.99	<6.04	<0.412	<7.43	<7.24	0.145 ± 0.116	<0.0561	<0.0561
Well 100[4]	<38.0	13.7 ± 17.1		<6.80	<7.05			
Bull Run Spring[4]	<52.2	<31.2	<0.390	<6.24	<5.64	0.949 ± 0.288	0.0863 ± 0.0848	0.777 ± 0.259
Buono Spring[4][5]	<25.8	<12.8	<0.345	<7.48	<6.21	0.947 ± 0.272	<0.0450	0.464 ± 0.188
RQ-20 Spring[5]	<9.46	11.8 ± 8.59	<0.378	<7.11	<5.40	0.639 ± 0.222	<0.0451	0.426 ± 0.180
CY Spring	<8.86	<6.16	<0.381	<7.45	<5.47	0.212 ± 0.121	<0.0412	0.159 ± 0.105
SIS (Outfall 007)[3][4][6]	<22.5	<12.5	0.425 ± 0.121	<5.93	<6.31	1.62 ± 0.354	0.0929 ± 0.0816	1.21 ± 0.303
Sewickley Sandstone Water-Bearing Zone								
Well 36	<4.14	<3.09	<0.326	<7.31	<6.57	1.73 ± 0.401	<0.0515	0.687 ± 0.246
Well 51	<10.8	<6.31	<0.628	<7.26	<7.23	1.17 ± 0.405	<0.0799	0.687 ± 0.307
Well 98	<4.66	<3.08		<7.29	<6.96			
Northeast Spring[5]	<8.90	<6.22	<0.370	<7.48	<6.50	0.874 ± 0.277	<0.0509	0.656 ± 0.239
Pittsburgh Sandstone Water-Bearing Zone								
Well 60	<8.46	<6.20	<0.431	<6.26	<6.17	0.641 ± 0.233	0.107 ± 0.0939	0.384 ± 0.179
Well 61	<8.60	<6.13		<7.48	<6.76			
Well 96	<6.16	3.47 ± 4.11		<7.46	<5.83			
Pittsburgh Coal Water-Bearing Zone								
Well 44	<5.60	<5.99	<0.426	<7.40	<6.24			
Well 44A	<5.77	8.19 ± 7.98	<0.345	<7.42	<7.62			
Well 48	<9.99	6.92 ± 8.17	<0.571	<7.37	<6.71	0.238 ± 0.141	<0.0503	0.0648 ± 0.0735
Well 63	<10.6	<6.23		<7.48	<6.41			
Well 95	<8.24	11.3 ± 8.48	<0.657	<7.48	<7.18	<0.0501	<0.0501	0.0861 ± 0.0846
DM176[3]	5.09 ± 7.64	6.05 ± 4.27	<0.523	<7.40	<6.74	0.232 ± 0.132	<0.0449	0.0772 ± 0.0758
Background								
NETL[3][4]	<18.8	<6.58	0.198 ± 0.112	<6.36	<6.90	0.452 ± 0.191	<0.0478	0.164 ± 0.114

NOTES:

(1) A "<" signifies the result was below the DLC, with the DLC being the reported value.

(2) The analytical method cannot distinguish between uranium-233 and uranium-234. The results are attributed to uranium-234 based on the source of the radioactivity.

(3) SIS = Springwater Intercept System; DM176 = Sample of Pittsburgh Coal Mine water discharge into the Dravosburg storm sewer system. NETL = National Energy Technology Laboratory (South Park, PA).

(4) Sample results indicated a high total dissolved solids (>3,000 mg/l). The high solids caused either a high gross alpha DLC result or a high degree of uncertainty in the sample result.

(5) These springs are included in the SIS. Samples were collected at access points in the drainage system.

(6) Positive Sr-90 value identified due to enhanced analysis method leading to a lower DLC.

TABLE 12

GROUNDWATER AND SURFACE WATER NONRADIOLOGICAL RESULTS

Units: mg/l

Water-Bearing Zone	Well No.	Analytes(1)(2)			
		PCE	TCE	DCE	
				cis-	trans-
Benwood Limestone	35	<0.001	<0.001	<0.001	<0.001
	57	<0.001	<0.001	0.0056	<0.001
	68	<0.001	<0.001	<0.001	<0.001
	80	0.00034 J	<0.001	<0.001	<0.001
	92	<0.001	<0.001	<0.001	<0.001
	100	<0.001	0.00053 J	<0.001	<0.001
Sewickley Sandstone	36	<0.001	<0.001	<0.001	<0.001
	51	0.980	0.220	0.120	<0.033
	65	8.500	0.620	0.150 J	<0.330
	98	<0.001	<0.001	<0.001	<0.001
Pittsburgh Sandstone	60	0.034	0.003	0.00038 J	<0.001
	61	0.00068 J	0.00033 J	<0.001	<0.001
	75	0.0011	<0.001	<0.001	<0.001
	96	<0.001	0.00039 J	0.0021	<0.001
Pittsburgh Coal	44A	0.001	0.00059 J	<0.001	<0.001
	95	<0.001	<0.001	<0.001	<0.001
Bull Run Stream Surface Water Results					
BR1		0.0068	0.00035 J	<0.001	<0.001
BR5		0.00079 J	<0.001	<0.001	<0.001

NOTES:

(1) Samples were analyzed for approximately 40 volatile organic compounds. Only the results for the potential contaminants of concern are reported (PCE = Tetrachloroethylene; TCE = Trichloroethylene; DCE = 1,2-Dichloroethylene). Results for the other volatile organic compounds were typically less than the minimum quantitation level that was generally 0.001 mg/l. The reported results represent the maximum results where more than one sample was analyzed from a sample location.

(2) Results with a "J" qualifier indicate that the associated result was less than the reporting limit but greater than or equal to the method detection limit and the concentration is an approximate value.

C. AIRBORNE EFFLUENTS

The purpose of the airborne effluent monitoring program is to determine the effectiveness of control methods, to measure concentrations in effluents for comparison with applicable standards and natural background levels, and to assess the effect of any inadvertent releases to the environment.

Sources

Sources of radioactive airborne materials included operations associated with examining nuclear fuel and reactor materials. Areas of the Site wherein unencapsulated radioactive materials were handled were equipped with filtered exhaust systems. The HEPA filters were preceded as necessary by prefilters to remove dust and large particulates. HEPA filters were tested upon installation and at least annually thereafter to ensure that high removal efficiencies (99.95%) are maintained.

Sources of airborne effluents not related to radiological operations were heating systems, such as gas and oil fueled boilers and space heaters, testing of diesel generating units, operation of diesel and natural gas emergency generators, and small-scale operations involving chemicals. Fuel burning and use of combustion equipment and other site operations are conducted in compliance with the Site's Air Operating Permit that was issued by the ACHD in June 2006. A renewal application for the air permit was submitted to the ACHD in December 2010 with a draft permit being received in 2013. Bettis operates in accordance with current regulations and conditions identified in the permit. Air exhausted from the Site's fume hoods was treated, where appropriate, by filtration to minimize the release of materials.

Airborne Monitoring

The samples and analyses specified below constitute the minimum samples and analyses conducted at the Site during 2018.

Radiological: Radioactive airborne effluents from the Site were continuously monitored using fixed-filter air stations operated at a constant, metered sample flow rate. Particulate radioactivity in the effluents was collected on 0.8 micron millipore filters. Charcoal impregnated filters were used to monitor the appropriate exhausts for gaseous radionuclides. Select exhausts were specifically monitored for plutonium-238 (Pu-238), europium-152 (Eu-152), Sr-90 and Cs-137 as required by 40 CFR 61 Subpart H. Filters were collected and analyzed at least weekly for gross alpha and gross beta radioactivity. Quarterly, the particulate filters from each exhaust were composited and analyzed for gross alpha, gross beta, Sr-90, and gamma-emitters. In addition, sampling for the short half-life (55 seconds) radon-220 (Rn-220) from former thorium handling areas was performed annually using a charcoal filter cold-trap method. The Site's radiological exhaust monitoring systems were in compliance with the EPA requirements in Reference (8).

Background airborne particulate radioactivity was monitored continuously using fixed-filter air samplers positioned off-site at locations (South Park, PA and West Mifflin, PA) which are approximately 7 miles and 1.5 miles, respectively, from the Site. These air filters were collected and analyzed weekly for gross alpha and gross beta radioactivity.

Nonradiological: There were no major chemical operations at the Site during 2018 which might generate significant quantities of airborne chemical pollutants. Estimates of particulate and gaseous emissions were used to ensure that applicable standards were met. Monitoring of nonradiological emissions was not required or necessary for most Bettis operations.

Airborne Analyses

Radiological: Particulate filter samples were analyzed for gross alpha and gross beta radioactivity at approximately 48 hours after collection to permit the decay of the naturally occurring, short-lived radon-thoron progeny that may have accumulated on the filters. The alpha and beta radioactivities were measured using a lead-shielded, gas-flow proportional counter. Quarterly, the sample filters were composited and analyzed for gross alpha and beta radioactivity as well as gamma-emitters. Typical DLCs for gross alpha and beta radioactivity were 2.0×10^{-16} µCi/ml and 4.0×10^{-16} µCi/ml, respectively.

Gamma analyses were conducted using a high purity germanium detector and a multichannel analyzer. A typical DLC for Cs-137 was 8.0×10^{-16} µCi/ml. Plutonium analyses of selected composites were performed using alpha spectrometry. A typical detection level for Pu-238 was 2.0×10^{-16} µCi/ml. In addition, Sr-90 analyses were performed on selected quarterly filter composites from potential source areas. A typical DLC for Sr-90 was 8.0×10^{-16} µCi/ml. The charcoal filters used for measuring Rn-220 releases were analyzed using the high purity germanium detector. The Rn-220 concentrations were determined from the characteristic photo-peak of lead-212 (Pb-212) which is the principal gamma-emitting product of Rn-220 decay.

Nonradiological: Discharges of nonradioactive airborne pollutants were not significant enough to require airborne monitoring.

Airborne Monitoring Results and Conclusions

Radiological: The results of the monitoring of particulate and gaseous radioactivity effluents from the Site during 2018 are summarized in Table 13. Specific results from the airborne monitoring program are discussed below. Although comparisons of the Site's particulate airborne radioactivity results were made to background particulate radioactivity levels measured at off-site locations, no background corrections were made to the Site's release results.

The average concentration of airborne particulate gross alpha radioactivity released during 2018 was less than 5.26×10^{-16} µCi/ml and the average concentration of airborne particulate gross beta radioactivity was less than 1.89×10^{-15} µCi/ml. In comparison, the average background gross alpha and gross beta airborne particulate radioactivity measured at the off-site locations were 9.08×10^{-16} µCi/ml and 1.62×10^{-14} µCi/ml, respectively. On average, the gross alpha airborne radioactivity concentration in air emitted from the Site was approximately a factor of 1.7 times less than the background airborne radioactivity levels. The gross beta airborne particulate radioactivity concentration in air emitted from the Site was approximately a factor of 8.6 times less than the background airborne radioactivity levels. Thus, the Site's filtration systems on the radiological exhausts are removing naturally occurring radioactivity from the air.

There were no detectable releases of Cs-137, Sr-90, Pu-238 or Eu-152 during 2018. The concentrations of these radionuclides listed in Table 13 are based on the DLC of the analyses.

TABLE 13

AIRBORNE EFFLUENT RADIOACTIVITY RESULTS

Radionuclide	Curies Released(1)	Half-life
Cesium-137 Strontium-90 Europium-152 Fission and Activation Products ($T_{1/2}$ >3 hr.)	<3.55E-08 <2.36E-08 <7.71E-08 <1.36E-07	30.1 years 28.8 years 13.5 years
Gross Beta Radioactivity(2)	≤1.24E-06	28.8 years/64.1 hours/ 30.1 years
Plutonium-238	<2.75E-09	87.7 years
Gross Alpha Radioactivity(3)	≤3.49E-07	87.7 years
Radon-220	2.89E+02	55.6 seconds

NOTES:
(1) A "<" signifies the result is below the DLC; a "≤" signifies the result are less than or equal to the DLC.
(2) Gross beta radioactivity is attributed equally to strontium-90, yttrium-90 and cesium-137.
(3) Gross alpha radioactivity is attributed to plutonium-238.

Based on the results of Rn-220 effluent measurements and pathway evaluations, the average concentration of Rn-220 at the location of the nearest off-site receptors was estimated to be approximately 1.24 x 10^{-11} µCi/ml. This level is over 1,600 times less than the Federal limit of 2.0 x 10^{-8} µCi/ml for Rn-220 (without progeny) in the air of uncontrolled areas. The releases of the very short-lived (55.6 seconds) Rn-220 gaseous radioactivity from the Site resulted in no adverse effect on the surrounding environment and did not result in radiation exposures above the EPA and U.S. DOE radiation dose standards.

The total airborne radioactivity released from the Site with radionuclide decay half-lives greater than one day was less than 1.73 x 10^{-6} Ci, or approximately equal to the amount of radioactivity in a common household smoke detector.

The results of the Site's airborne radiological effluent monitoring program demonstrate the effectiveness of control methods. The results also show that the amount of airborne radioactivity released was too small to result in any measurable change in background radioactivity levels in the environment. The concentrations of radioactivity released from the Site during 2018 were below the applicable limits for radioactivity in ambient air. Furthermore, the estimated radiation dose to any member of the public from the airborne radioactivity released was too low to measure and could only be determined by calculational models, which showed that the estimated dose was significantly below the radiation protection standard established by the EPA in Reference (8).

Nonradiological: The results of evaluations and calculations for the Site's sources of airborne chemical pollutants are summarized below.

Heating System Exhaust

The boilers and space heating systems at the Site were fueled primarily with natural gas. No fuel oil was combusted in 2018. The heating systems were operated in accordance with the ACHD, Article XXI, Air Pollution Control regulations and the Site's Air Operating Permit. Conservative estimates of the pollutant releases utilizing EPA emission factors were made. These calculations showed that the

airborne emissions from the Site's heating systems are well below the applicable local limits identified in Reference (9).

Diesel Generator Compatibility Testing

The Computing Center emergency generators and diesel generator compatibility testing at the Site were fueled with No. 2 ultra low sulfur diesel fuel. These processes were conducted in accordance with the Air Operating Permit. Conservative estimates of the pollutant releases utilizing EPA emission factors were made. These calculations showed that the airborne emissions from the Computing Center emergency generators and diesel generator compatibility testing were well below the permit limits allowed in Reference (9).

Asbestos Removal Work

Asbestos removal work was conducted in compliance with the Federal, State and local requirements to limit the potential discharge of asbestos fibers to the environment. During 2018, the ACHD conducted three clearance inspections of asbestos abatement projects and released each project work area to unrestricted public use.

Engineering controls are strictly followed and enforced at the Bettis Atomic Power Laboratory in accordance with regulatory requirements. Contingency plans to limit the potential release of asbestos fibers to the environment in the case of a spill have also been developed. Any issues with asbestos containing material are immediately rectified through proper notifications or abatement action. There were no instances in 2018 resulting in an uncontrolled release of asbestos fibers to the environment.

D. SEDIMENT, SOIL, AND VEGETATION

The purpose of the sediment and soil monitoring programs is to monitor for the migration of existing radioactive and chemical residues. The purpose of the stream vegetation radiological monitoring program is to monitor for the potential uptake of radioactivity into stream vegetation.

Sources

The source of the radioactive and chemical residues in portions of the storm sewer system and the Bull Run Stream basin is from operations conducted in the 1950s and 1960s. A significant amount of contaminated soil along Bull Run was removed in 1976 and 1977 and disposed of off-site at a DOE burial ground.

Sediment, Soil, and Vegetation Monitoring

Radiological: Routine sediment samples were collected semiannually from the streambeds of the Site's effluent streams and from an off-site control stream, as shown in Figure 5. Seven sediment samples were collected along the length of the Bull Run and Thompson Run Streams. One sample each was collected from the Northeast Area Stream and an off-site control location. The sediment sample from the off-site location is a background sample since there are no known nuclear or radiological facilities in operation which could release radioactive effluents to these streams. These samples were analyzed for gross alpha and gross beta radioactivity, Sr-90, and gamma emitters.

Sediment samples were also collected from the stilling basin at the Bull Run Monitoring Station and from select on-site storm sewer components. These sample locations are shown in Figure 5. The sediment samples were analyzed for gross alpha and gross beta radioactivity, Sr-90, and gamma-emitters.

Historically, soil samples were collected from within and below the drainage ditch at the base of the IWS. Due to the installation of the flow separator in 2010, these historic sample locations are no longer accessible. As such, soil samples are now collected biennially from the runoff area below the IWS hillside. The current soil sampling area below the IWS is shown in Figure 6. Soil samples were collected below the IWS in 2018.

Vegetation samples were collected from select locations in and along the Site's effluent streams. The vegetation samples were analyzed for Sr-90 radioactivity and gamma-emitters.

Nonradiological: Sediment samples were collected from the catch basin at the Bull Run Monitoring Station and from select storm sewer components as shown in Figure 5. The sediment samples were analyzed for PCBs, VOCs, and mercury.

Sediment samples were collected from two locations (BR1 and BR5) in the Bull Run Stream as shown in Figure 5. These samples were analyzed for VOCs.

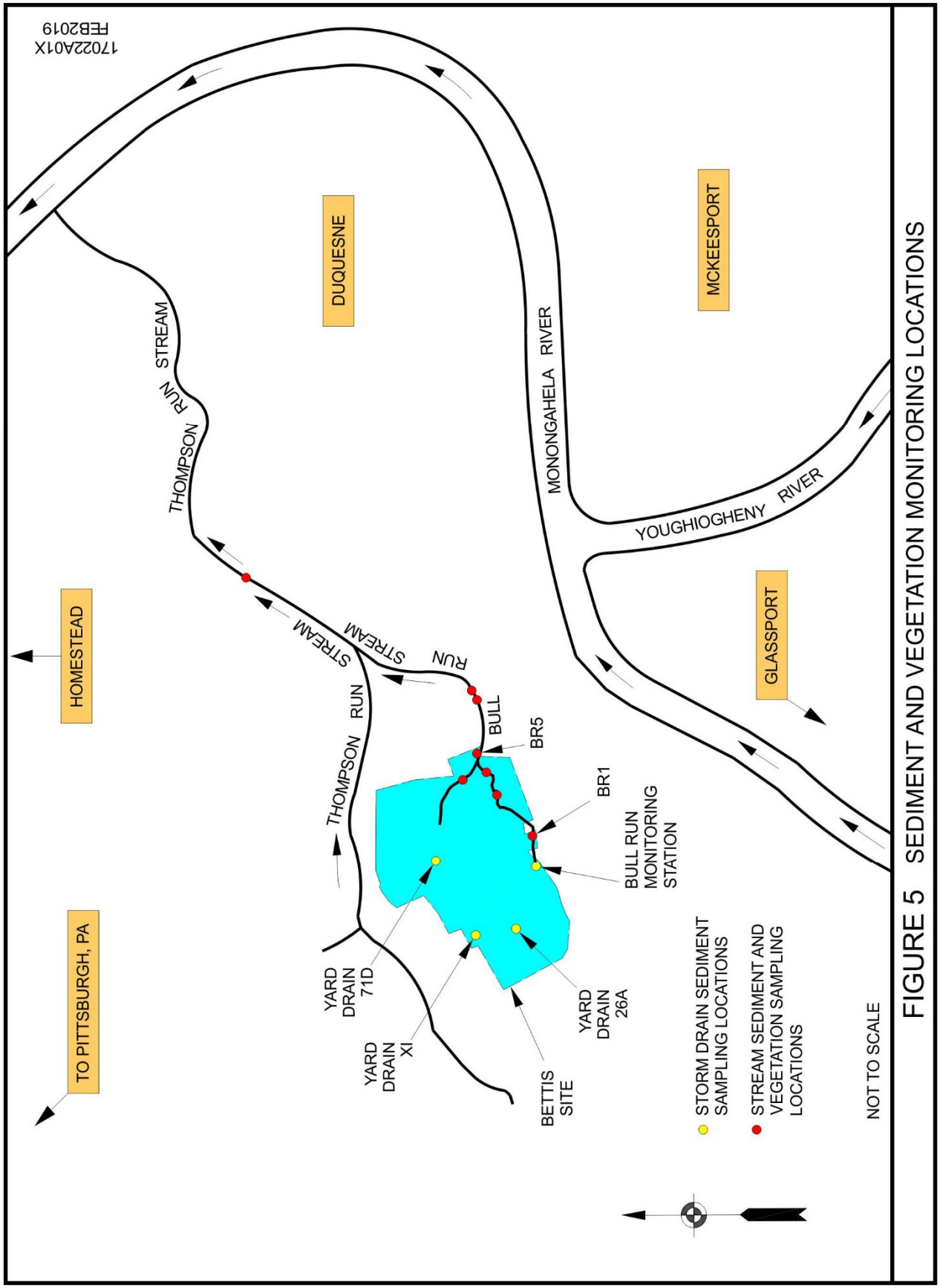

FIGURE 5 SEDIMENT AND VEGETATION MONITORING LOCATIONS

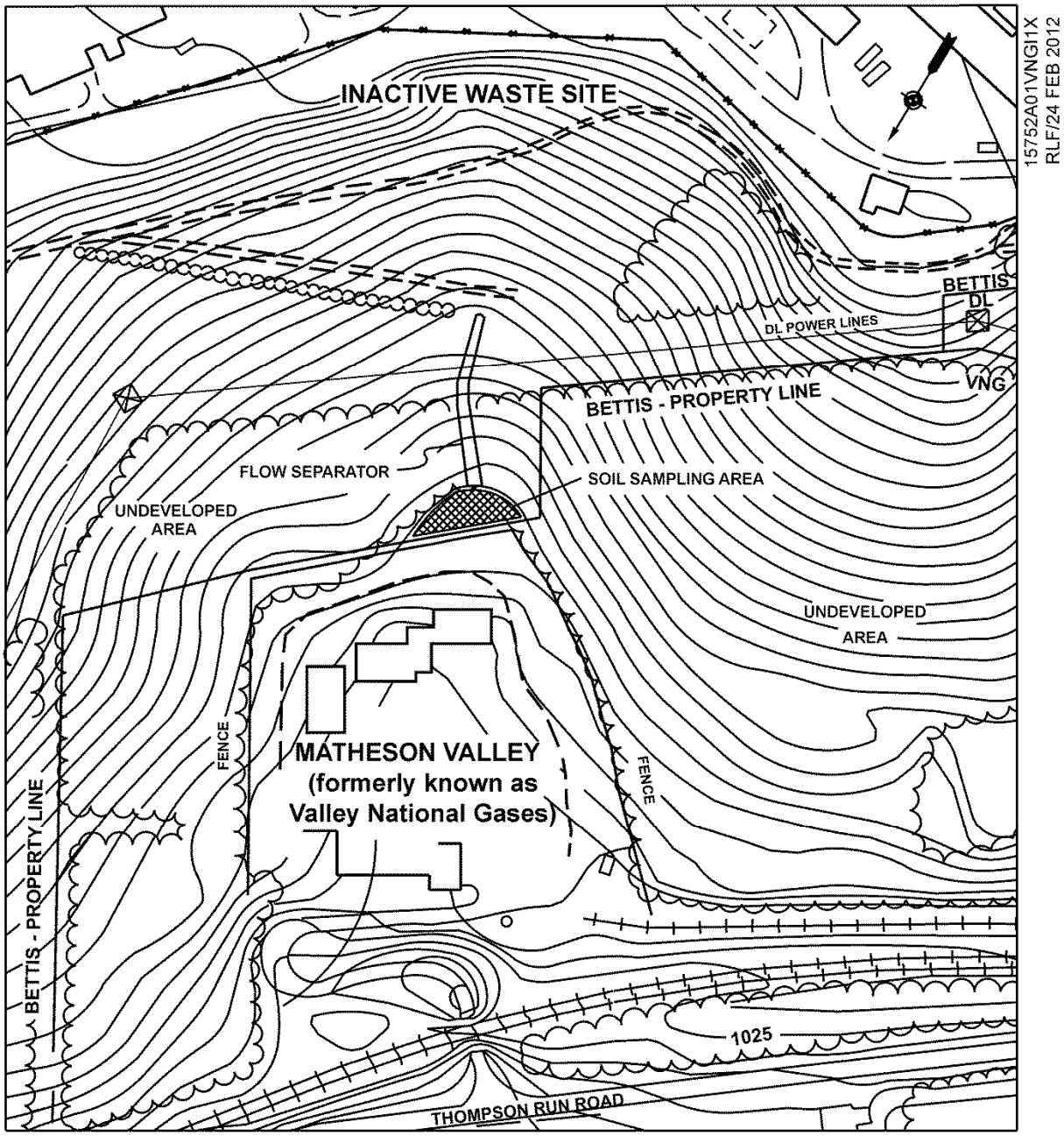

FIGURE 6: SOIL SAMPLE LOCATIONS BELOW THE INACTIVE WASTE SITE

Sediment, Soil, and Vegetation Analyses

Radiological: The sediment samples were oven dried, milled, homogenized, and screened to remove large stones and extraneous materials. The vegetation samples were air dried, chipped, and blended. Aliquots of the homogenized sediment samples were uniformly distributed on a planchet and the gross alpha and beta radioactivities were measured by counting using a lead shielded, gas-flow proportional counter. Gamma analyses were performed on the sediment and vegetation by counting with a gamma spectrometry system. Typical DLCs for the gamma analyses were 0.1 pCi/g for sediment and 0.03 pCi/g for vegetation.

Sr-90 analyses of the sediment and vegetation samples were performed utilizing a standard strontium radiochemical procedure. The strontium was chemically separated and the sample was analyzed for beta radioactivity using the proportional counter described above. Typical DLCs for Sr-90 ranged from 0.1 to 0.3 pCi/g.

Nonradiological: Analysis of sediments and soils were performed using test methods described in Reference (5).

Sediment, Soil, and Vegetation Monitoring Results and Conclusions

Radiological: The results of the radioactivity analyses of sediment, soil and vegetation are summarized in Tables 14, 15, and 16 as discussed below.

The alpha and beta radioactivity levels in the Bull Run Stream, Thompson Run Stream and the Northeast Area Stream sediment samples were consistent with the gross alpha and beta radioactivity levels in the background (off-site control location) stream sediment.

Low levels of Cs-137 radioactivity, up to a maximum concentration of 1.66 pCi/g, were detected in the sediment samples from the Bull Run and Thompson Run Streams. These radioactivity concentrations are less than those found naturally occurring in loose leaf spinach and are consistent with levels of Cs-137 found in the environment due to fallout and with previous results attributed to historic Bettis operations during the 1950's and 1960's. The radioactivity levels for Sr-90 and Co-60 in the sediment from the Bull Run, Thompson Run and the Northeast Area Streams were below DLCs and were consistent with background radioactivity levels. The radioactivity levels for uranium in these sediment samples are consistent with natural levels of uranium in the soil in this area.

Cs-137 was not detected above DLC in Bull Run Monitoring Station samples. A sample from one on site yard drain indicated Cs-137 was present at a concentration of 0.0250 pCi/g. This result is consistent with levels of Cs-137 found in the environment due to fallout and also with previous results attributed to historic Bettis operations during the 1950's and 1960's. The radioactivity levels for uranium in the storm water outfall monitoring station and yard drains are consistent with natural levels of uranium in the soil in this area.

The radioactivity levels in vegetation collected in the Site's effluent streams and the Thompson Run Stream were consistent with natural levels of radioactivity in vegetation and are summarized in Table 15.

In summary, the data did not indicate any uptake of residual radioactivity in stream vegetation, nor were there any significant changes in the residual radioactivity levels in stream sediments. These results are consistent with previously reported values in prior annual reports.

The results of the soil samples collected from the soil sampling area below the IWS are provided in Table 16. The radioactivity levels in most of these samples indicate low levels of Cs-137 and uranium. The maximum concentrations of these isotopes are Cs-137, 0.219 pCi/g; U-234, 1.52 pCi/g; U-235, 0.0665 pCi/g; and U-238, 1.59 pCi/g. These results are consistent with previous results and show that there has not been any buildup of radioactivity in the area since monitoring was initiated.

TABLE 14

STORM SEWER AND STREAM SEDIMENT RADIOACTIVITY RESULTS

Units: pCi/g

Sample Location	Radionuclides(1)						
	Gross Alpha	Gross Beta	Sr-90	Co-60	Cs-137	U-235(2)	U-238(2)
Stream Sediment							
Bull Run/ Thompson Run Streams	<4.35 To 17.8 ± 9.83	13.9 ± 4.05 To 33.2 ± 4.24	<0.303 To <0.522	<0.0291 To <0.0500	0.164 ± 0.0504 To 1.66 ± 0.134	0.110 ± 0.0595 To 0.200 ± 0.0978	1.67 ± 0.508 To 4.69 ± 0.805
Northeast Area Stream	<3.78 To 15.5 ± 9.02	12.8 ± 2.64 To 28.7 ± 4.00	<0.500	<0.0413 To <0.0477	0.0491 ± 0.0511 To <0.0503	0.187 ± 0.0892 To 0.207 ± 0.120	3.01 ± 0.650 To 4.18 ± 0.857
BKG(3)	<3.76 To 3.98 ± 5.88	11.0 ± 2.44 To 14.4 ± 3.13	<0.565	<0.0269 To <0.0364	<0.0306 To <0.0415	0.0932 ± 0.0730 To 0.100 ± 0.0790	1.36 ± 0.424 To 3.01 ± 0.643
Storm Sewer Sediment							
Bull Run Monitoring Station(4)	<3.88 <3.83 <3.84	7.58 ± 2.64 4.28 ± 2.22 5.89 ± 2.37	<0.484 <0.495 <0.463	<0.0630 <0.0483 <0.0703	<0.0578 <0.0488 <0.0742	0.0996 ± 0.0719 0.148 ± 0.0969 0.242 ± 0.419	1.85 ± 0.864 <1.21 3.53 ± 1.06
YD 26A	11.8 ± 8.63	10.5 ± 3.61	<0.350	<0.0399	<0.0412	<0.305	<0.819
YD 71D	6.06 ± 6.92	8.80 ± 3.10	<0.349	<0.0158	<0.0187	0.0350 ± 0.0382	0.962 ± 0.295
YD XI	9.43 ± 7.93	15.0 ± 3.69	<0.500	<0.0221	0.0250 ± 0.0148	0.0560 ± 0.0432	0.673 ± 0.351

NOTES:
(1) A "<" signifies the result was below the DLC, with the DLC being the reported value.
(2) Uranium results are from gamma spectrometry.
(3) BKG – background sample from a control stream at the National Energy Technology Laboratory in South Park, PA
(4) Results are from replicate or multiple samples.

TABLE 15

STREAM VEGETATION RADIOACTIVITY RESULTS

Units: pCi/g

Sample Location	Radionuclides[1]		
	Sr-90	Co-60	Cs-137
Bull Run/Thompson Run	<0.0613 To <0.123	<0.0282 To <0.0542	<0.0274 To <0.0615
BKG[2]	<0.103	<0.0732	<0.0632

NOTES:
(1) A "<" signifies the result was below the DLC, with the DLC being the reported value.
(2) BKG = background sample from National Energy Technology Laboratory in South Park, PA.

TABLE 16

SOIL SAMPLES BELOW THE INACTIVE WASTE SITE RADIOLOGICAL RESULTS

Units: pCi/g

Sample Location[1]	Radionuclides						
	Gross Alpha	Gross Beta	Strontium-90	Cesium-137	Uranium-233/234[2]	Uranium-235	Uranium-238
IWS-04	14.6 ± 8.87	18.4 ± 3.56	<0.557	0.219 ± 0.0420	1.04 ± 0.172	0.0404 ± 0.0301	1.04 ± 0.172
IWS-05	14.4 ± 9.17	19.4 ± 4.58	<0.536	0.213 ± 0.0834	1.52 ± 0.205	0.0665 ± 0.0365	1.59 ± 0.211

NOTES:
(1) Refer to Figure 6 for sample locations.
(2) The analytical method cannot distinguish between uranium-233 and uranium-234. The results are attributed to uranium-234 based on the source of the radioactivity.

Nonradiological: The results of the nonradiological sediment samples collected and analyzed in 2018 as part of Bettis' routine environmental monitoring program are summarized in Table 17 and discussed below.

The results of sediment sampling for chemical residues in the Site's storm sewer system, in the Bull Run Monitoring Station, and in the Bull Run Stream are shown in Table 17. The sample locations are shown in Figure 5. The results show low levels of PCE, the primary VOC of concern, but not its degradation products, were detected in the stream samples at levels consistent with previous results. These results are consistent with previous data for the storm sewer system.

In November 2015, chemical analysis of the residue found in the bottom of an on-site historical electrical distribution system manhole indicated the presence of PCBs in excess of 50 ppm. The maximum PCB concentration found in the residue was 2,060 ppm. A courtesy notification was made to EPA Region III regarding the event. All contaminated residue has been removed from the manhole and work to remediate this area is ongoing.

TABLE 17

STORM SEWER AND STREAM SEDIMENT NONRADIOLOGICAL RESULTS

Units: mg/kg

Sample Location	VOCs(1)(2)				PCBs(2)			Hg
	PCE	TCE	DCE		1248	1254	1260	
			cis-	trans-				
Storm Sewer Sediment								
Bull Run Monitoring Station	<0.00558	<0.00558	<0.00279	<0.00279				
YD 26A	<0.00650	<0.00650	<0.00650	<0.00650	<0.024	<0.024	<0.024	<0.046
YD 71D	<0.00640	<0.00640	<0.00640	<0.00640	<0.023	0.047	<0.023	<0.050
YD XI	<0.00820	<0.00820	<0.00820	<0.00820	<0.027	0.050	<0.027	<0.049
Bull Run Stream Sediment								
BR1	0.051	<0.00391	<0.00195	<0.00195				
BR5	<0.00357	<0.00357	<0.00178	<0.00178				

NOTES:

(1) VOC results are presented only for the potential contaminants-of-concern.
PCE = Tetrachloroethylene; TCE = Trichloroethylene; DCE = 1,2-Dichloroethylene

(2) Data Qualifiers:
< = Compound not detected above the indicated reporting limit.

E. RADIATION MONITORING

The purpose of the environmental radiation monitoring program is to measure the ambient radiation levels around the Site to confirm that site operations have not altered the natural radiation background levels at or near the site perimeter.

Radiation Sources

The sources of radiation at the Site include small specimens of irradiated and unirradiated fuel materials which were handled, processed, and stored at the Site. There are no nuclear reactors at the Site.

Radiation Monitoring

Environmental radiation levels were monitored in the vicinity of the Site with a network of lithium fluoride thermoluminescent dosimeters (TLDs). The approximate locations of the Site TLDs are shown on Figure 7. Control TLDs were posted at locations remote from the Site to measure the natural background radiation levels typical for western Pennsylvania. The control TLDs were located in nearby communities (Crafton, Export, Whitehall, North Huntingdon, Monroeville, Jefferson Hills, Penn Hills, Franklin Park, and Ellsworth, PA). All TLDs were posted for quarterly exposure periods.

In addition to the TLD network, which was the primary monitoring method, a radiation survey was conducted around the site at the location of the TLDs.

Radiation Analyses

The environmental TLDs used in this program contain four lithium fluoride dosimeter elements that are doped with magnesium (Mg), copper (Cu) and phosphorous (P); or LiF (MCP). It is a characteristic of LiF (MCP) that radiation causes internal changes that make the material, when subsequently heated, give off an amount of light that is directly proportional to the radiation dose received. To ensure accuracy of the TLD reader results, calibration checks are performed prior to processing of the TLDs and quality control dosimeters are interspersed with the environmental monitoring dosimeters per approved calibration and dosimetry processing procedures.

Radiation surveys were conducted using a portable µR/hour radiation survey meter (Ludlum Measurements, Inc. Model 12S) at approximately three feet above the ground. This meter was calibrated with Cs-137 within six months prior to use and source checked for proper operation immediately prior to use.

Radiation Monitoring Results and Conclusions

The TLD results in Table 18 summarize the radiation levels measured during each quarter. The annual average (summation of quarterly results) radiation exposure for the on-site TLDs was 72.7 mrem. The annual average radiation exposure at the off-site locations was 76.8 mrem. The quarterly perimeter and off-site results are analyzed to identify any statistically significant difference. The quarterly analysis demonstrated that the exposure received by an individual located at the site

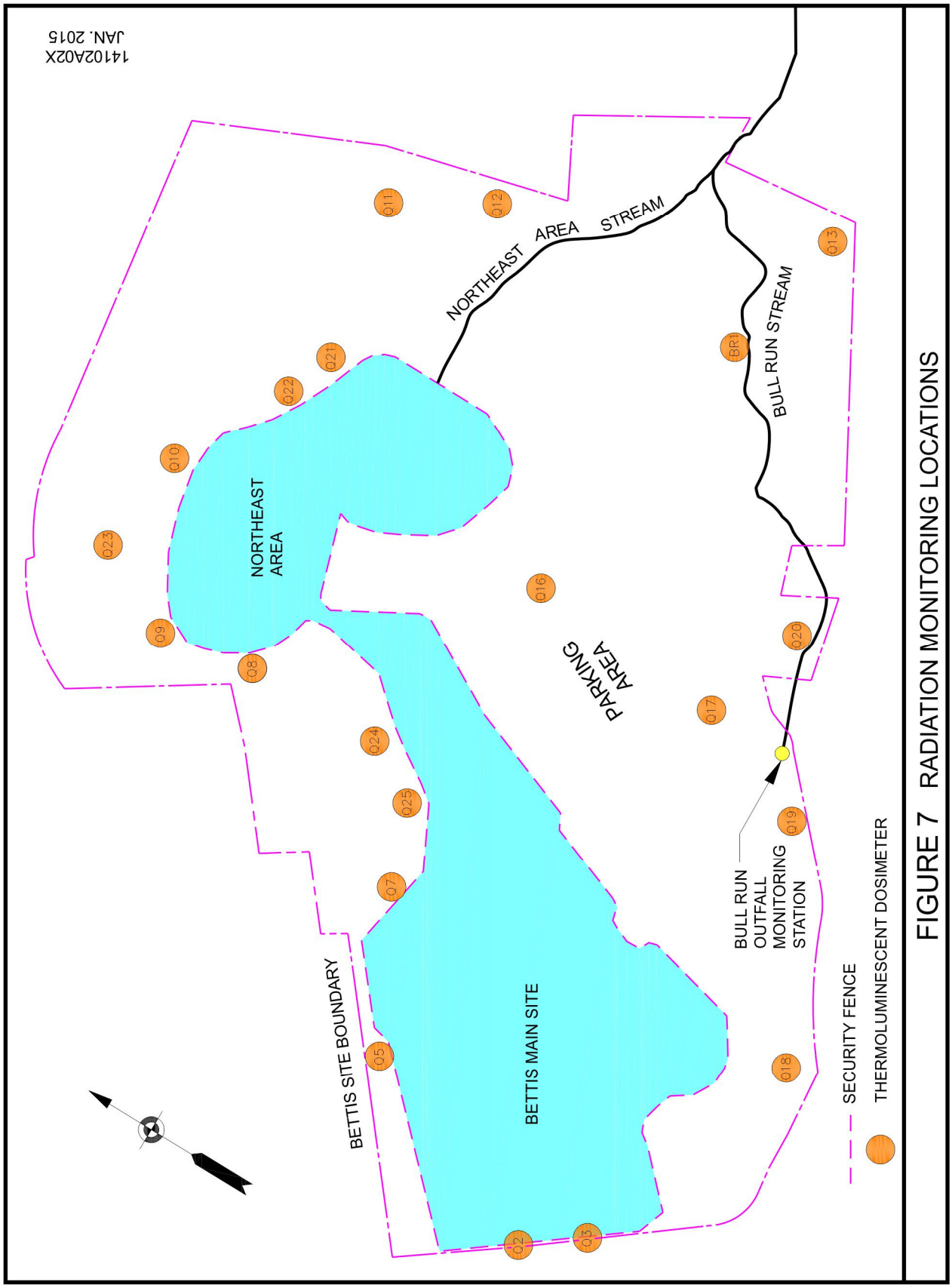

FIGURE 7 RADIATION MONITORING LOCATIONS

TABLE 18

THERMOLUMINESCENT DOSIMETER (TLD) ENVIRONMENTAL RADIATION RESULTS

Quarterly Exposure Period	On-Site Results			Off-Site Background Results		
	Number of Meas.	Range (mrem)	Average (mrem)	Number of Meas.	Range (mrem)	Average (mrem)
First	21	17 – 24	20.6	9	18 – 24	21.7
Second	21	14 – 20	17.1	9	15 – 20	18.1
Third	21	12 – 19	15.7	9	13 – 18	16.0
Fourth	21	16 – 22	19.3	9	17 – 24	21.0

perimeter was not statistically different from that received from background radiation in the surrounding area.

The radiation dose rates measured during the site perimeter radiation survey averaged approximately 0.00890 mrem/hour which, when integrated over the TLD exposure period in 2018, predicted an annual exposure of 78.0 mrem.

The 2018 radiation monitoring results were consistent with the range of natural radiation levels of 82 to 104 mrem/year observed in an U.S. Public Health Service survey of the northwest and southwest areas of Pennsylvania, Reference (11).

Also, the radiation monitoring results were consistent with the range of natural radiation levels of 79 to 105 mrem/year determined by an aerial radiation survey, Reference (10), which encompassed a 100-square-mile area around the Site. Therefore, it was concluded that the radiation exposure to the general public at the site perimeter was not above the exposure received from natural background radiation. The data (direct radiation measurements, airborne measurements, and effluent water measurements) show that current site operations do not cause any measurable change in the natural radiation environment surrounding the Site.

F. INACTIVE COKE GAS LINES

Large diameter underground inactive coke gas lines are widespread throughout the Pittsburgh, Pennsylvania area. The contents of the inactive coke gas lines under the Bettis Site are monitored to detect changes in the volume of residual materials and to monitor the integrity of the lines.

Sources

There are two, abandoned, underground, 40-inch diameter coke gas transmission lines that transect the site. The lines contain coke gas residues (typically sludge from condensed coke gas) and water in some locations. The known and potential locations of the lines and monitoring ports are shown in Figure 8. The lines were used to transmit coke gas from a nearby coke production facility to various steel production facilities in the Pittsburgh area, and are unrelated to activities at the Site. The sections of these pipelines that traverse the Site are only small portions of the entire length of the abandoned coke gas lines in Pittsburgh and the surrounding communities. Reference (1) contains detailed information on the lines and contents.

Sections of both lines have been removed at various times to permit building construction on-site. One section was removed in 2000 as a corrective measure (refer to the "Corrective Measures Implementation" section of this report). The sludge and water that accumulated immediately behind the cap at SP-1 was removed in 2004, and the decades-old cap near SP-1 was replaced to ensure its integrity. A section of coke gas line at SP-3 was removed in 2006 for building construction in that area. SP-3A and SP-3B ports were installed in the remaining coke gas line sections.

Monitoring Results and Conclusions

The volume of residual materials (sludge and water) is measured annually at the locations shown in Figure 8. For 2018, the volume of residual materials at sample ports SP-1, SP-3A, SP-3B, SP-6, SP-9, and SP-S/R was generally consistent with previous measurements.

In summary, the 2018 and previous monitoring results show that two of the five monitored sections appear to be intact. Communication of the coke gas residues with the environment at SP-1, SP-3A and SP-S/R appears to be minor, as evidenced by the absence of noticeable contaminants in the soil during excavations at these locations. Changes in the water levels at these three locations are typically small and infrequent, except as noted above, and support this conclusion. Monitoring of the lines will continue, and actions will be taken to mitigate the possible release of residues to the environment if necessary, even though these lines are not associated with the Bettis Atomic Power Laboratory.

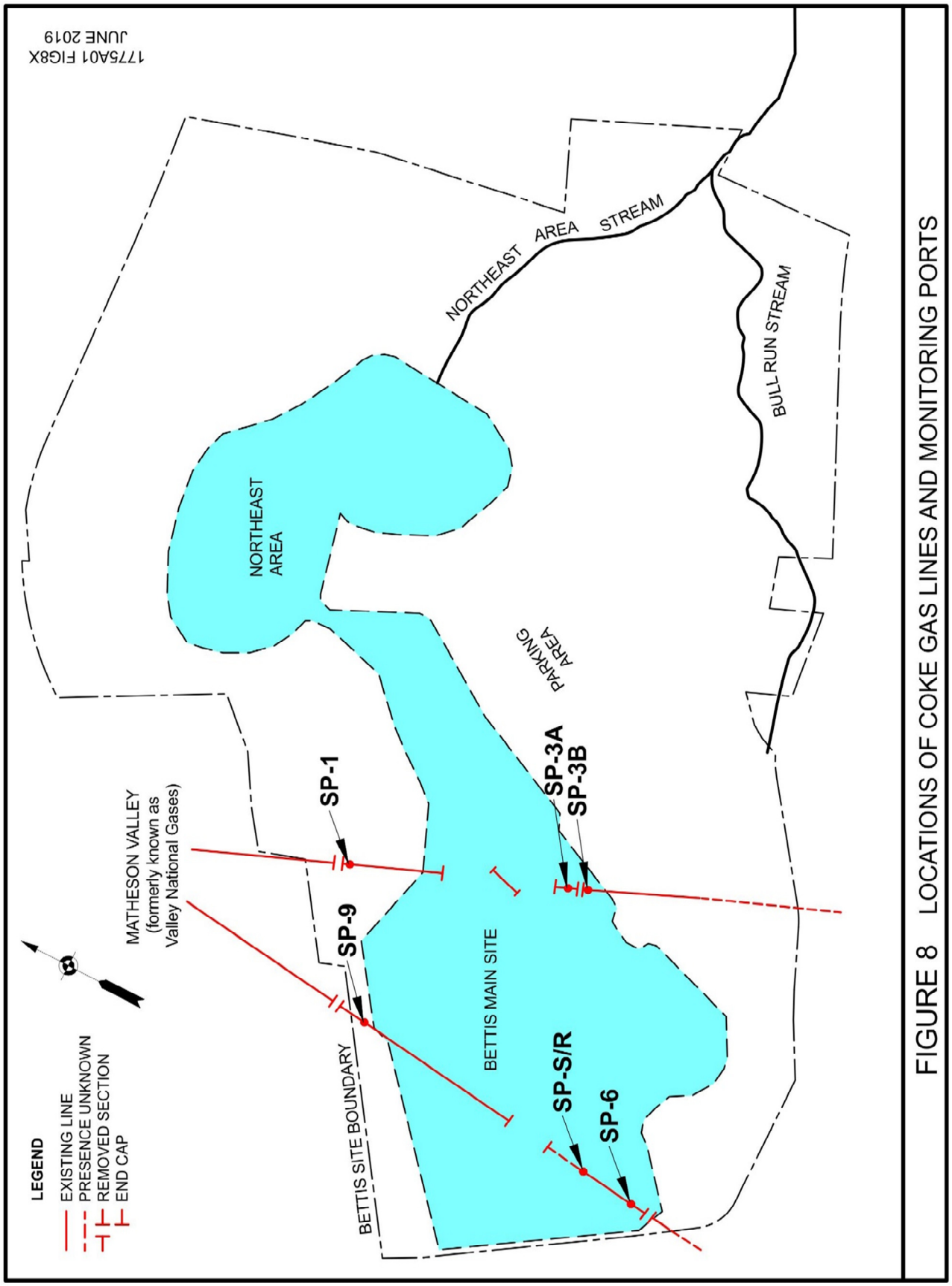

FIGURE 8 LOCATIONS OF COKE GAS LINES AND MONITORING PORTS

ASSESSMENT OF RISK FROM CHEMICAL RESIDUES

A risk assessment was prepared as part of the Site's Resource Conservation and RFI. This assessment was prepared using the Superfund related methodology outlined in Reference (12). The detailed assessment, presented in Reference (1), is summarized below.

The objective of the assessment was to determine the reasonable maximum exposure of on-site and off-site populations to environmental contamination at the Site. The media containing chemical residues are soil, groundwater, surface water (springs and streams), and sediment. Residues whose concentrations exceeded the U.S. EPA Region III's risk-based screening levels were selected as potential contaminants-of-concern. The residues evaluated were largely volatile organic compounds PCBs, and polynuclear aromatic hydrocarbons (PAHs).

Risks were evaluated for realistic industrial land-use scenarios, now and in the future. EPA exposure parameters were used for off-site commercial/industrial workers who could be potentially exposed to contaminated soil below the IWS. Site-specific exposure parameters were used for pathways where standard EPA values were not available or were not appropriate. All exposure pathways judged to be complete now and in the future were quantified. Groundwater exposure was not quantified because Bettis and off-site populations that are hydrologically downgrade from the Site receive municipal water and this is unlikely to change in the foreseeable future.

The risk assessment quantified carcinogenic risk and noncarcinogenic hazard for four potentially exposed populations:

- On-site construction workers exposed to chemical residues in soil;
- Off-site commercial/industrial workers exposed to chemical residues in soil;
- Trespassing children exposed to chemical residues in water and sediment in springs and streams; and
- Off-site children exposed to chemical residues in water in a spring and sediment in a stream.

Based on EPA criteria, the calculated carcinogenic risk and noncarcinogenic hazard values were compared with the values of 0.000001 (1.0×10^{-6}) and 1.0, respectively, which represent acceptable risk levels.

For on-site construction workers engaged in excavation activities, carcinogenic risks were quantified for all on-site locations where potential contaminants-of-concern were present. The noncarcinogenic hazard could be calculated only for two sites and the values were several orders of magnitude below the comparison criterion of 1.0. The estimated carcinogenic risks did not exceed the comparison criterion of 1.0×10^{-6} at any location, with the highest being 5.4×10^{-7} for soil in the IWS (Figure 6).

The estimated carcinogenic risk to commercial workers from exposure to PCBs and PAH compounds in surface soil in the main drainage ditch below the IWS (Figure 6) was about 2.0×10^{-5}. This risk estimate used highly conservative assumptions in calculating intake (i.e., exposure for 250 days/year for 25 years) and the actual risk was considered to be much lower. In October 2010, installation of a flow separator in the ditch covered the affected soil with gravel and additional soil, thus precluding access and exposure to the contaminants-of-concern. Under current conditions, the actual carcinogenic risk would be much lower than the comparison criterion of 1.0×10^{-6}.

Exposure to surface water and sediment in the on-site and off-site streams and springs was quantified for children, the only group that might have more than occasional contact with these media. The highest estimated risk was 1.0×10^{-7} for exposure to Thompson Run Stream sediment, which is below the comparison criterion of 1.0×10^{-6}. Noncarcinogenic hazards were several orders of magnitude below the comparison criterion of 1.0.

In summary, chemical residues in the environment at the Site do not pose significant health risks to potentially exposed populations using reasonable maximum exposure assumptions. The only study area with a carcinogenic risk estimate exceeding the comparison criterion was the drainage ditch area below the IWS, with a maximum carcinogenic risk of about 2.0×10^{-5}. However, exposure (skin contact, ingestion, and inhalation) for 250 days/year for 25 years required to achieve this risk is no longer possible due to the installation of the flow separator and the potential risk to workers is far less than 1.0×10^{-6}. Noncarcinogenic risks were all significantly less than the comparison criterion of 1.0.

The 2018 results of analyses for chemical residues in the environment support the conclusions of the risk assessment.

CORRECTIVE MEASURES IMPLEMENTATION

After approving the *Final Resource Conservation and Recovery Act (RCRA) Facility Investigation Report,* Reference (1), the U.S. EPA approved the *Final Corrective Measures Study Report*, Reference (13). The purpose of the study was to evaluate and recommend, where needed, corrective measures that would protect human health and the environment. The need for corrective measures was judged primarily from a risk assessment of the carcinogenic risks and noncarcinogenic hazards potentially posed by the chemical contaminants-of-concern at the Site. The most prevalent residue is tetrachloroethylene, a common degreasing chemical that is the same solvent used to dry-clean clothing. The risk assessment, discussed in the previous section, demonstrated that the chemical residues in the environment at the Site do not realistically present a significant carcinogenic risk or noncarcinogenic hazard to human health. Therefore, extensive corrective measures are not necessary to protect human health now or in the foreseeable future.

The *Final Corrective Measures Study Report* proposed corrective measures to ensure that risks to human health remain low and to further reduce the chemical residues in the environment. In 1997, the EPA issued its final recommendations for corrective measures. Bettis proactively implemented and completed the majority of the recommended corrective measures to the EPA's satisfaction prior to implementation of a CMIO in April 2001. These activities included the construction and operation of a SIS to collect and treat groundwater that discharges to a local stream; this system is operated under a Consent Order with the Commonwealth of Pennsylvania. Other activities included removal of contaminated sediment and/or liquid from portions of the Site's stormwater sewer system and from underground coke gas lines (remaining from historical non-Bettis usage), removal of a localized area of contaminated soil, and removal of a breached section of an abandoned coke gas line. Institutional controls are in place to ensure personnel safety and health for activities that could involve contact with environmental media containing chemical residues. Monitoring programs for groundwater, surface water and sediment, storm sewers, and the coke gas lines are also in place to ensure the conclusions of the *RCRA Facility Investigation Report* remain valid.

The CMIO provides a standard EPA protocol for implementation of the remaining EPA corrective measures: soil vapor extraction of the Bettis Landfill, a pre-design groundwater study on the hillside below the IWS, and continuation of routine environmental monitoring.

Enhanced Soil Vapor Extraction (ESVE) is a process that physically removes volatile contaminants from soils by inducing airflow through the soil. The air is then passed through activated carbon filter units to capture the volatile contaminants prior to discharge to the atmosphere. The purpose of the vapor extraction corrective measure is to reduce a potential source of groundwater contamination. Construction of the vapor extraction system was completed and the system was placed in operation in 2004. On April 6, 2011, the ESVE system was shut down after reaching ALARA criteria established for the system. Soil attainment and delineation sampling was conducted in 2011 to obtain EPA corrective measures completion approval in accordance with the CMIO. Based on the results of the soil attainment and delineation sampling, in March 2012, both the EPA and PADEP agreed that the ESVE system can be permanently terminated and the system can be removed. System removal activities were completed in September 2012. During the course of ESVE operation, approximately 5,900 pounds of VOCs were removed from the Landfill area. A Certification of Completion Report for the remediation of VOCs in soil at the Bettis Landfill was subsequently submitted to and approved by the EPA. The EPA has concluded that the corrective measures from the 2001 CMIO have been fully implemented and media standards have been met. The purpose of the groundwater study on the hillside below the IWS

was to determine the sources and quantities of groundwater that occasionally are released to the surface as seepage and to determine if a subsurface drainage system is a necessary or appropriate remedy for this area. The study was completed in 2003 and the study results issued to the EPA. The study concluded that seepage originates from two separate water-bearing zones and typically reabsorbs back into the ground on what is now U. S. DOE property. Bettis Atomic Power Laboratory recommended installation of a flow separator in the wet-weather ditch to preclude the mixing of seepage containing trace levels of site residues with surface water that could potentially carry the seepage off-site. The EPA subsequently determined and documented in a supplemental Statement of Basis that, based on additional investigations, groundwater impacted by the IWS does not present an unacceptable risk and that further action is limited to monitoring the Matheson Valley (formerly known as Valley National Gases) property annually to confirm the absence or presence of water supply wells or plans to install such wells. Any use or planned use of groundwater will be reported to the EPA. To be further protective of the environment, Bettis developed plans and, in 2010, constructed the flow separator after obtaining PADEP concurrence that this action is an acceptable measure to preclude the off-site migration of groundwater seepage and sediment. Further, sampling of water and sediments in runoff associated with the ditch have been discontinued following installation of the flow separator as agreed by the EPA.

On September 11, 2013, the EPA terminated the 2001 CMIO. The remaining continual obligations of the CMIO are implemented under the Corrective Action Permit (CAP) issued by the EPA on August 21, 2013. Routine environmental monitoring is ongoing under the requirements of the CAP, and the results will be reported on an annual basis to the EPA.

RADIATION DOSE ASSESSMENT

Effluent monitoring results at the Site during 2018 demonstrated that radioactivity releases were below applicable Federal radioactivity limits. Radiation exposure to the general public from airborne releases was too low to measure and could only be determined with calculational models using the airborne effluent radioactivity data. Airborne effluent radioactivity data which were below the DLCs were assumed to be present at the DLC. Therefore, a conservative assessment of the radiation dose-to-man was performed by analyzing the exposure pathways whereby radioactivity might be transmitted from the Site to the general public. The following potential exposure pathways were considered in this assessment. The first two pathways contribute more than 99% of the dose-to-man.

- Direct radiation from residual radioactivity in the Bull Run Stream basin;
- Inhalation of airborne radioactivity;
- Exposure to ground deposits from airborne radioactivity;
- Immersion in the atmosphere containing the released airborne radioactivity;
- Ingestion of food contaminated by deposition of airborne radioactivity;
- Ingestion of radioactivity in the drinking water supply; and
- Direct radiation from Site operations.

Specific radionuclide composition of the airborne releases was factored into the assessment. The effective dose equivalent for each exposure pathway was explicitly calculated for each radionuclide and applicable progeny. The air pathway calculations used wind direction data and meteorological parameters that were measured by the Site's meteorological monitoring system for 2018. The Site's meteorological monitoring system measures wind speed, gusts, wind direction, temperature, relative humidity, and inches of rain. The measurements are integrated over 15-minute intervals. The system is part of the National Atmospheric Release Advisory Center (NARAC) network developed by Lawrence Livermore National Laboratory to model the atmospheric release of radioactive materials. The population distribution in the vicinity of the Site was based on census data from 2010. The atmospheric dispersion of the Site's radioactive airborne releases and resulting effective dose equivalent were calculated using an U.S. EPA-approved computer program described in Reference (14). The radiation dose assessment attributed to Site operations during 2018 is presented in Table 19. Radiation doses were calculated for the whole body of individuals at locations of maximum exposure to the nearest off-site receptor and for the total population within 50 miles of the Site.

The results in Table 19 show that the maximum whole body radiation exposure which any member of the public could hypothetically receive due to past and present operations ranged from 0.185 to 1.20 mrem. Nearly all of this very low potential effective dose equivalent would be from gaseous radioactivity and from exposure to the Bull Run soil and sediments that contain residual radioactivity from operations during the 1950's and 1960's. Based on a conservative estimate that an individual would spend as much as one hour per day, every day of the year, walking along the Bull Run stream bank in the areas with radiation levels above background, the annual hypothetical dose received would be less than 1.0 mrem. This dose reflects the results of the radiation survey conducted in 2016.

TABLE 19

Annual Radiation Dose-to-Man from Site Operations

Pathway	Dose to Maximally Exposed Individual (mrem)	(mSv)	% of DOE Limit (100 mrem/yr)	Estimated Population Dose (person-rem)	(person-Sv)	Population within 80 km (50 miles)	Estimated Background Radiation Population Dose (person-rem)
Air	1.85E-01	1.85E-03	1.85E-01	2.42	2.42E-02	3.00E+06	9.0E+05
Water	None		-	None			
Other Pathways	<1.0	<1.0E-02	<1.0	1.00E-02	1.00E-04		
All Pathways	<1.2	<1.2E-02	<1.2	2.43	2.43E-02		

This maximum potential effective dose equivalent is well below the most restrictive dose limits of the NRC and the U.S. DOE. The maximum potential effective dose equivalent is less than 1% of the approximately 311 mrem dose a person receives each year from naturally occurring radiation in the environment, Reference (15). Therefore, the radioactivity and the resultant radiation from Bull Run Stream sediment do not present a hazard to the public. The dose resulting from the low levels of radioactivity in the Site's airborne effluents is significantly less than the limits of the EPA in Reference (8).

In conclusion, the maximum radiation exposure to any member of the public as a result of operations at the Bettis Site during 2018 was substantially below the radiation exposure limits established by the DOE, the NRC, and the EPA. Moreover, the accumulated radiation exposure received due to Site operations during 2018 by the total population of approximately 3,000,000 within 50 miles of the Site was conservatively estimated to be 2.43 person-rem, which is negligible compared to the approximately 900,000 person-rem dose received from natural background radiation. Therefore, the radioactivity released from the Site, as a result of past and present operations, has not resulted in any significant radiation exposure to the general public.

QUALITY ASSURANCE

The Bettis Quality Assurance Program (QAP) is conducted to ensure the accuracy and precision of effluent and environmental sampling, analysis, and reporting.

The program consists of the following elements:

Internal Quality Assurance Procedures

- Personnel training and qualification
- Written procedures for sampling, sample analysis, and computational methods
- Calibration of sampling and sample analysis equipment
- Internal quality assurance sample analyses
- Data review/validation and computation check

The internal quality assurance procedures start with the training of all personnel involved in the collection and analysis of samples, in accordance with established internal policies. Personnel are not permitted to perform sampling and sample analysis until they are trained and have demonstrated the ability to properly perform their duties. Written procedures cover collection and analysis of samples, the computation of results, and the calibration of sampling and analytical equipment. Internal quality assurance procedures also provide for a system of duplicate (or replicate) analyses of the same sample, blank samples, and the analyses of spiked samples to demonstrate precision and accuracy. All measurement data are assessed to detect anomalies, unusual results, and trends.

Participation in a Quality Assessment Program Administered by a Commercial Laboratory

Bettis participates in a QAP administered by a commercial laboratory, Environmental Resource Associates (ERA). The QAP provides an independent verification of the accuracy and precision of analyses of effluent and environmental monitoring samples. The results in the ERA QAP are summarized in Table 20. The data demonstrates satisfactory performance.

Subcontractor Quality Assurance Procedures

Vendor subcontractor laboratories perform non-radioactive effluent and environmental sample analyses. Bettis maintains a quality assurance program to ensure the accuracy and precision of the subcontractor analytical results. This includes submitting trip blanks or field blanks and replicate samples along with routine samples for analysis. If unsatisfactory results are obtained, follow-up investigations are performed to correct the problems.

Program Audits

Periodic audits are conducted that examine the effluent and environmental monitoring programs to ensure compliance with all procedures and applicable federal and state regulations.

TABLE 20

ENVIRONMENTAL RESOURCE ASSOCIATES (ERA) RADIOANALYTICAL QUALITY ASSURANCE RESULTS

Study Dates	Media	Radionuclide	Reported Value(1)(2)	Assigned Value(1)	Evaluation(3)
MRAD-28 03/19/18 - 05/18/18	Water	Gross Alpha	19	29.0	Acceptable
		Gross Beta	69	73.1	Acceptable
		Cobalt-60	1530	1480	Acceptable
		Cesium-134	1200	1330	Acceptable
		Cesium-137	332	328	Acceptable
		Plutonium-238	60	66.1	Acceptable
		Plutonium-239	82	91.8	Acceptable
		Strontium-90	958	781	Acceptable
		Uranium-234	123	132	Acceptable
		Uranium-238	126	131	Acceptable
MRAD-28 03/19/18 - 05/18/18	Air Filter	Cobalt-60	690	665	Acceptable
		Cesium-134	163	204	Acceptable
		Cesium-137	917	865	Acceptable
MRAD-28 03/19/18 - 05/18/18	Soil	Cobalt-60	9740	8060	Acceptable
		Cesium-134	5680	5330	Acceptable
		Cesium-137	5220	4210	Acceptable
		Thorium-232	1260	1240	Acceptable
MRAD-28 03/19/18 - 05/18/18	Vegetation	Cobalt-60	462	491	Acceptable
		Cesium-134	1590	1950	Acceptable
		Cesium-137	2040	2160	Acceptable
MRAD-29 09/17/18 - 11/16/18	Air Filter	Cobalt-60	1210	1130	Acceptable
		Cesium-134	792	921	Acceptable
		Cesium-137	401	373	Acceptable
		Americium-241	63	64.1	Acceptable
MRAD-29 09/17/18 - 11/16/18	Water	Cobalt-60	1640	1510	Acceptable
		Cesium-134	2210	2310	Acceptable
		Cesium-137	951	898	Acceptable

NOTES:
(1) Units are pCi/liter for water, pCi/kilogram for soil and vegetation samples, and pCi/filter for air filter samples.
(2) The reported value is the result of multiple analyses determinations.
(3) Acceptable performance indicates that the measurement fell between the 15th and 85th percentile. The not acceptable designation is established at less than the 5th percentile and greater than the 95th percentile.

RADIATION AND RADIOACTIVITY

GENERAL INFORMATION

This section provides general information on radiation and radioactivity for those who may not be familiar with the terms and concepts.

Man has always lived in a sea of natural background radiation. This background radiation was and is as much a part of the earth's environment as the light and heat from the sun's rays. There are three principal sources of natural background radiation: cosmic radiation from the sun and outer space, radiation from the natural radioactivity in soil and rocks (called 'terrestrial radiation'), and internal radiation from the naturally radioactive elements that are part of our bodies. A basic knowledge of the concepts of radiation and radioactivity is important in understanding how effective control programs are in reducing radiation exposures and radioactivity releases to levels that are as low as reasonably achievable.

RADIATION

In simple terms, radiation is a form of energy. Microwaves, radio waves, x-rays, light, and heat are all common forms of radiation. The radiation from radioactive materials (radionuclides) is in the form of particles or rays. During the decay of radionuclides, alpha, beta, and gamma radiation are emitted.

Alpha radiation consists of small, positively charged particles of low penetrating power that can be stopped by a sheet of paper. Radionuclides that emit alpha particles include radium, uranium, and thorium.

Beta radiation consists of negatively charged particles that are smaller than alpha particles but are generally more penetrating and may require up to an inch of wood or other light material to be stopped. Examples of beta emitters are Sr-90, Cs-137, and Co-60.

Gamma radiation is an energy emission like an x-ray. Gamma rays have great penetrating power but are stopped by up to several feet of concrete or several inches of lead. The actual thickness of a particular shielding material required depends on the quantity and energy of the gamma rays to be stopped. Most radionuclides emit gamma rays along with beta or alpha particles.

Each radionuclide emits a unique combination of radiations that is like a "fingerprint" of that radionuclide. Alpha or beta particles and/or gamma rays are emitted in various combinations and energies. Radionuclides may be identified by measuring the type, relative amounts, and energy of the radiations emitted. Measurement of half-life and chemical properties may also be used to help identify radionuclides.

Radiation Dose Assessment

Body tissue can be damaged if enough energy from radiation is absorbed. The amount of energy absorbed by body tissue during radiation exposure is called "absorbed dose." The potential biological effect resulting from a particular dose is based on a technically defined quantity called "dose equivalent." The unit of dose equivalent is called the Roentgen equivalent man or rem. Another quantity called "effective dose equivalent" is a dose summation that is used to estimate the risk of health effects when the dose is received from sources that are external to the body and from radioactive materials that are within the various body tissues. The traditional unit of effective dose equivalent,

which is used in the United States is also the rem, while the standard international (SI) unit is the Sievert (one Sievert is equal to 100 rem). The rem is a unit that is relatively large compared with the level of radiation doses received from natural background radiation or projected as a result of releases of radioactivity to the environment. The millirem (mrem, or one thousandth of a rem), is frequently used instead of the rem. The rem and mrem are better understood by relating to concepts that are more familiar.

Radiation comes from both natural and man-made sources. Natural background radiation includes cosmic radiation from the sun and outer space, terrestrial radiation from radioactivity in soil, radioactivity in the body, and inhaled radioactivity.

The National Council on Radiation Protection and Measurements estimates that the average member of the population of the United States receives an annual effective dose equivalent of approximately 311 mrem from natural background radiation. This is composed of approximately 33 mrem from cosmic radiation, 21 mrem from terrestrial radiation, 29 mrem from radioactivity within the body and 228 mrem from inhaled radon and its decay products. The cosmic radiation component in the United States varies from 22 mrem at Honolulu, Hawaii to 65 mrem in Colorado Springs, Colorado. The terrestrial component varies from approximately 10 mrem on the Atlantic and Gulf Coastal Plain to about 40 mrem in the mountainous regions of the west. The dose from inhaled radon and its decay products is the most variable because of fluctuations in radon concentrations within houses due to changes in weather patterns and other factors such as changes in living habits.

The average natural background radiation level measured in the vicinity of the Bettis Site is approximately 79 mrem per year. Individual locations will vary based on soil composition, soil moisture content and snow cover.

In addition to natural background radiation, people are also exposed to man-made sources of radiation, such as medical and dental x-rays and conventional fluoroscopy, computed tomography, nuclear medicine and interventional fluoroscopy. The average radiation dose from these sources is about 300 mrem per year. Other man-made sources include consumer products such as building products (brick and concrete), lawn and garden fertilizer, loose leaf spinach, and bananas. Additionally, an airplane trip typically results in increased radiation exposure. A cross country airline flight from New York to Seattle results in a dose of about 3 mrem.

RADIOACTIVITY

All materials are made up of atoms. In the case of a radioactive material, these atoms are unstable and give off energy in the form of rays or tiny particles in order to reach a stable state. Each type of radioactive atom is called a radionuclide. Each radionuclide emits a characteristic form of radiation as it gives off energy. Radionuclides change as radiation occurs, and this transition is called radioactive decay. The rate at which a particular radionuclide decays is measured by its half-life. Half-life is the time required for one-half the radioactive atoms in a given amount of material to decay. For example, the half-life of the man-made radionuclide Co-60 is 5.3 years. This means that during a 5.3-year period, half of the Co-60 atoms initially present will have decayed. In the next 5.3 year period, half the remaining Co-60 atoms will have decayed, and so on.

The half-lives of radionuclides differ greatly. The half-life of naturally occurring Rn-220, for instance, is only 55 seconds. In contrast, U-238, another naturally occurring radionuclide has a half-life of 4.5 billion years.

Through the decay process, each radionuclide changes into a different nuclide or atom - often becoming a different chemical element. For example, naturally occurring radioactive Th-232, after emitting its radiation, transforms to a second radionuclide, which transforms to a third, and so on. Thus, a chain of eleven radionuclides is formed including Rn-220, before nonradioactive lead-208 (Pb-208) is formed. Each of the radionuclides in the series has its own characteristic half-life and type of radiation. The chain finally ends when the newest nuclide is stable. The uranium chain starts with U-238 and proceeds through 13 radionuclides, ending with stable lead-206 (Pb-206). All of these naturally occurring radionuclides are present in trace amounts in the soil in your backyard as well as in many other environmental media.

Measuring Radioactivity

The curie (Ci) is the common unit used for expressing the magnitude of radioactive decay in a sample containing radioactive material. The analogous SI unit to the Ci is the Becquerel (Bq). Specifically, the curie is that amount of radioactivity equal to 3.7×10^{10} (37 billion) disintegrations per second and a Bq is equal to one disintegration per second. For environmental monitoring purposes, the curie is usually too large a unit to work with conveniently and is broken down into smaller values such as the microcurie (μCi one millionth of a curie or 10^{-6} Ci) and the picocurie (pCi one trillionth of a curie or 10^{-12} curie). Older wristwatches that were painted with radium to allow the numbers or segments to “glow in the dark” contained about one microcurie (1 μCi) of radium on the dial. The average person has about one tenth (0.1) microcurie of naturally occurring potassium-40 in his body. Typical soil and sediment samples contain about one picocurie (1 pCi) of natural uranium per gram.

Sources of Radioactivity

Of the radioactive atoms that exist in nature, some have always existed and natural processes continually form others. For example, uranium has always existed, it is radioactive, and it occurs in small but variable concentrations throughout the earth. Radioactive carbon and tritium, on the other hand, are formed by cosmic radiation striking atoms in the atmosphere. Radionuclides can also be created by man. For example, radionuclides are created in nuclear reactors and consist of fission products and activation products. The fission products are the residues of the uranium fission process that produces the energy within the reactor. The fission process also produces neutrons that interact with structural and other materials in the reactor to form activation products. Because of the nature of the fission process, many fission products are unstable and, hence, radioactive. Most fission products have short lives and are retained within the nuclear fuel itself; however, trace natural uranium impurities in reactor structural materials release small quantities of fission products to the reactor coolant.

It should be noted that a certain level of "background" fission-product radioactivity also exists in the environment, primarily due to past atmospheric nuclear weapons testing. Although the level is very low, these fission products are routinely detected in air, food, and water when analyzed with extremely sensitive instruments and techniques.

CONTROL OF RADIATION AND RADIOACTIVITY

To reduce the exposure of persons to ionizing radiation to “as low as reasonably achievable” (ALARA), controlling the use and disposal of radioactive materials and comprehensive monitoring programs to measure the effectiveness of these controls are required. Effluent streams that may contain radioactive materials must be treated by appropriate methods to remove the radioactive materials and the effluent monitored to ensure that these materials have been reduced to concentrations that are as low as is reasonably achievable and are well within all applicable guidelines and requirements prior to discharge.

GLOSSARY

Activation Products – As cooling water circulates through the reactor, certain impurities present in the water and even components of the water itself can be converted to radioactive nuclides (they become "activated"). Important activation products present in reactor coolant water include radionuclides of corrosion and wear products (Co-60, Fe-59, Co-58, Cr-51), of impurities dissolved in the water (Ar-41, Na-24, C-14) and of atoms present in the water molecules (tritium). Of these, the predominant radionuclide and also the one with the most restrictive limits is Co-60.

Alkalinity – The measurable ability of solutions or aqueous suspensions to neutralize an acid.

Alpha Radioactivity – A form of radioactivity exhibited by certain radionuclides characterized by emission of an alpha particle. Many naturally occurring radionuclides including radium, uranium, and thorium decay in this manner.

Background Radiation – Radiation present in the environment as a result of naturally occurring radioactive materials and cosmic radiation. Generally treated as including widespread low-level human-made radiation sources, including fallout.

Beta-Gamma Radioactivity – A form of radioactivity characterized by emission of a beta particle and/or gamma rays. Many naturally occurring radionuclides such as lead-212, bismuth-212, and bismuth-214 decay in this manner.

Calibration – The adjustment of a system and the determination of system accuracy using known sources and instrument measurements of higher accuracy.

Collective Effective Dose Equivalent – The sum of the effective dose equivalents of all individuals in an exposed population within an 80 kilometer (50 mile) radius and is expressed in units of person-rem.

Composite Sample – A sample that is comprised of a number of grab samples over the compositing period. In some cases, the composite sample obtained may be proportional to effluent flow and is called a proportional sample or flow-composited sample.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) – Also known as "Superfund," CERCLA was enacted by Congress in 1980 to clean up inactive hazardous waste sites that presented great risk to public health and the environment.

Confidence Interval – Statistical terminology for the error interval (±) assigned to numerical data. A two sigma (2σ) confidence interval means there is 95% confidence that the true value (as opposed to the measured one) lies within the (±) interval. The 95% is the confidence level (See (±) value, Standard Deviation of the Average).

Contaminant – Any physical, chemical, biological, or radiological substance in a location or concentration that is not naturally occurring.

Curie (Ci) – The curie is the common unit used for expressing the magnitude of radioactive decay in a sample containing radioactive material. Specifically, the curie is that amount of radioactivity equal to

3.7×10^{10} (37 billion) disintegrations per second. For environmental monitoring purposes, the curie is usually too large a unit to conveniently work with and is broken down to smaller values. (See Microcurie and Picocurie.)

Data Validation – A systematic review of a data set to identify outliers or suspect values. More specifically, data validation refers to the systematic process of independently reviewing a body of analytical data against established criteria to provide assurance that the data are acceptable for their intended use. This process may use appropriate statistical techniques to screen out impossible or highly unlikely values.

Decision Level Concentration (DLC) – The quantity of radioactivity above which a decision is made that a net amount of radioactivity is present with a five percent probability of erroneously reporting net radioactivity when none is present (false positive).

Dose Equivalent – The quantity that expresses the biological effects of radiation doses from all types (alpha, beta-gamma) of radiation on a common scale. The unit of dose equivalent is the rem.

Dosimeter – See Thermoluminescent Dosimeters.

Duplicate Sample – A sample that is created by splitting existing samples before analysis and treating each split sample as a separate sample. The samples are then analyzed as a quality assurance method to assess the precision in the analytical process.

Effluent – Any treated or untreated air emission or liquid discharge to the environment, including storm water runoff.

Field Blank – A sample of laboratory distilled water that is put into a sample container at the field collection site and is processed from that point as a routine sample. Field blanks are used as a quality assurance method to detect contamination introduced by the sampling procedure.

Effective Dose Equivalent – The effective dose equivalent is the sum of the dose equivalent to the whole body from external sources plus the dose equivalents to specific organs times a weighting factor appropriate for each organ. The weighting factor relates the effect of individual organ exposure relative to the effect of exposure to the whole body. The unit of effective dose equivalent is the rem.

Fission Products – During operation of a nuclear reactor, heat is produced by the fission (splitting) of "heavy" atoms, such as uranium, plutonium or thorium. The residue left after the splitting of these "heavy" atoms is a series of intermediate weight atoms generally termed "fission products." Because of the nature of the fission process, many fission products are unstable and, hence, radioactive. Most fission products have short lives and are retained within the nuclear fuel itself; however, trace natural uranium impurities in reactor structural materials release small quantities of fission products to the reactor coolant.

It should be noted that a certain level of "background" fission product radioactivity exists in the environment, primarily due to atmospheric nuclear weapons testing. The level is very low, but may be detectable when environmental samples are analyzed with extremely sensitive instruments and techniques.

Grab Sample – A single sample that is collected and is representative of the stream or effluent.

Groundwater – Subsurface water in the pore spaces and fractures of soil and bedrock units.

Half-Life – A time period associated with a radionuclide that specifies how long it takes for one half of a given quantity of radioactivity to decay away. Half-lives may range from fractions of a second to millions of years.

High Efficiency Particulate Air (HEPA) Filter – A throwaway, extended-media, dry type filter with a rigid casing enclosing the full depth of the pleats. The filter shall exhibit a minimum efficiency of 99.97% when tested at an aerosol diameter of 0.3 micrometers aerodynamic diameter.

High Purity Germanium Gamma Spectrometer System – A High Purity Germanium gamma spectrometer system is a sophisticated set of components designed for characterizing and quantifying the radionuclides present in a sample. This system makes use of the fact that during the decay of most radionuclides, one or more gamma rays are emitted at energy levels characteristic of the individual radionuclide. For example, during the decay of Co-60, two gamma rays of 1.17 and 1.33 million electron volts (MeV) are emitted while the decay of Argon-41 produces one gamma ray of 1.29 MeV. The high purity germanium detector used in this system is capable of detecting and very precisely resolving differences in gamma ray energy levels and sending this information along to electronic components where it is processed and evaluated.

Influent – The water entering the pump, the filter or other equipment. Water going into the pump is called the influent, while water leaving the pump is called the effluent.

Long-Lived Gamma Radioactivity – Two very important characteristics of radionuclides are the length of time it takes for a given amount to decay away and the type of radiation emitted during decay. From an environmental standpoint, some of the most significant radionuclides are those whose "life" is relatively long and that also emit penetrating gamma radiation during decay. Two radionuclides of concern in these respects are Co-60 (a corrosion and wear activation product) and Cs-137 (a fission product). (See Half-Life, Beta-Gamma Radioactivity.)

Method Detection Limit – The lowest value at which a non-radiological sample result shows a statistically positive difference from a sample in which no constituent is present.

Microcurie (µCi) – One millionth of a curie (10^{-6} Ci). The typical radium dial watch might contain 1 µCi of radioactive material. (See Curie and Picocurie.)

Milligrams per liter (mg/l) – A unit of concentration commonly used to express the levels of impurities present in a water sample. A milligram is a thousandth of a gram. A milligram per liter is equal to a part per million.

Millirem (mrem) – One thousandth of a rem (10^{-3} rem).

Osmotic Pressure – The pressure produced by a solution in a space that is enclosed by a differentially permeable membrane.

Outfall – A point of discharge (e.g., drain or pipe) of liquid effluent into a stream, river, ditch, or other water body.

Person-Rem – The sum of the individual dose equivalents or effective dose equivalents received by each member of a certain group or population. It is calculated by multiplying the average dose per person by the number of persons within a specific geographic area. For example, a thousand people each exposed to 0.001 rem would have a collective dose of one person-rem.

pH – A measure of the acidity or alkalinity of a solution on a scale of 0 to 14 (low is acidic, high is alkaline or caustic, 7 is neutral).

Picocurie (pCi) – One trillionth of a curie (10^{-12} Ci). Typical soil and sediment samples contain approximately one pCi of natural uranium per gram. (See Curie and Microcurie)

± Value (plus or minus value) – An expression of the uncertainty in sample results. The magnitude of the (±) value depends on the number of samples, the size of the sample, intrinsic analytical uncertainties and the degree of confidence required. The (±) value assigned to data in this report is for the 95% confidence level (See Confidence Interval).

Polychlorinated Biphenyls (PCBs) – Halogenated aromatic hydrocarbons formed by the chlorination of biphenyl molecules. PCB's were commonly used in transformers as a dielectric fluid because of their stability.

Polynuclear Aromatic Hydrocarbon (PAH) – Multi-ring compounds found in fuels, oils, and creosote. These are also common combustion products.

Practical (Minimum) Quantitation Limit – The lowest concentration that can be reliably achieved in non-radiological samples within specified limits of precision and accuracy during routine laboratory operating conditions.

Quantitation limit – The lowest level at which a chemical may be accurately and reproducibly quantified. The sample quantitation limit is typically three to five times higher than the analytical method detection limit.

Radionuclides – Atoms that exhibit radioactive properties. Standard practice for naming radionuclides is to use the name or atomic symbol of an element followed by its atomic weight (e.g., cobalt-60 or Co-60, a radionuclide of cobalt). There are several hundred known radionuclides, some of which are man-made and some of which are naturally occurring. Radionuclides can be differentiated by the types of radiation they emit, the energy of the radiation and the rate at which a known amount of the radionuclide decays away. (See Half-Life.)

Resource Conservation and Recovery Act (RCRA) – A federal law that established a structure to track and regulate hazardous wastes from the time of generation to disposal. The law requires safe and secure procedures to be used in treating, transporting, storing, and disposing of hazardous substances. RCRA is designed to prevent new, uncontrolled hazardous waste sites. RCRA particularly addresses chemical issues; Atomic Energy Act regulated radioactivity is exempted from RCRA.

Rem – The unit of dose equivalent and effective dose equivalent. The standard international (SI) unit of dose equivalent and effective dose equivalent is the Sievert (Sv), which is equal to 100 rem.

Standard Deviation of the Average – A term used to characterize the uncertainty assigned to the mean of a set of analyzed data (See Confidence Interval, (±) Value).

Suspended Solids – Particulate matter, both organic and inorganic suspended in water. High levels of suspended solids not only affect the aesthetic quality of water by reducing clarity, but may also indirectly indicate other undesirable conditions present. The analysis for suspended solids is performed by passing a sample of water through a filter and weighing the residue.

Thermoluminescent Dosimeters (TLDs) – TLDs are sensitive monitoring devices that record accumulated dose due to radiation. The TLDs used by the Bettis Atomic Power Laboratory for environmental monitoring consist of small chips of lithium fluoride (LiF) encased in appropriate materials and strategically located at site perimeter and off-site locations. Thermoluminescent Dosimeters derive their name from a property that LiF crystals exhibit when exposed to radiation and subsequently heated-that of emitting light proportional to the amount of radiation exposure received (thermoluminescence). The emitted light can then be read out on special instrumentation and correlated to the amount of radiation dose accumulated. The TLDs used by Bettis for environmental monitoring are specially selected for their accuracy and consistency of results.

Total Dissolved Solids (TDS) – Total Dissolved Solids is used as a general indicator of water quality. As the name describes, TDS tests measure the amount of all dissolved solids in the water. These solids are primarily minerals/salts, but can also include organic matter.

Volatile Organic Compound (VOC) – An organic (carbon-containing) compound that evaporates (volatilizes) readily at room temperature.

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