Department of Energy

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April 3, 2024

Ms. April Webb
Interim Federal Facility Agreement Manager
Division of Waste Management
Kentucky Department for Environmental Protection
300 Sower Boulevard, 2nd Floor
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PPPO-02-10027349-24

Mr. Victor Weeks
Federal Facility Agreement Manager
U.S. Environmental Protection Agency, Region 4
61 Forsyth Street
Atlanta, Georgia 30303

Dear Ms. Webb and Mr. Weeks:

TRANSMITTAL OF THE OPERATION AND MAINTENANCE AND ENVIRONMENTAL MONITORING PLAN FOR SOLID WASTE MANAGEMENT UNITS 1 AND 211-A REMEDIAL ACTIONS FOR VOLATILE ORGANIC COMPOUND SOURCES TO THE SOUTHWEST GROUNDWATER PLUME AT THE PADUCAH GASEOUS DIFFUSION PLANT, PADUCAH, KENTUCKY, DOE/LX/07-2501&D1

Enclosed for review is the Federal Facilities Agreement (FFA) secondary document, *Operation and Maintenance and Environmental Monitoring Plan for Solid Waste Management Units 1 and 211-A Remedial Actions for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2501&D1.

In accordance with Section XX of the Paducah FFA, the U.S. Environmental Protection Agency and the Kentucky Department for Environmental Protection have a 90-day review period. If the FFA Parties have no substantive comments, DOE requests a letter of concurrence.

If you have any questions or require additional information, please contact Angus MacKelvey at (270) 349-7526.

Sincerely,

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Date: 2024.04.03 14:09:02 -05'00'

April Ladd
Federal Facility Agreement Manager
Portsmouth/Paducah Project Office

Enclosure:
Operation and Maintenance and Environmental Monitoring Plan for Solid Waste Management Units 1 and 211-A Remedial Actions for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky DOE/LX/07-2501&D1

Administrative Record File—SWP-PD

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DOE/LX/07-2501&D1
Secondary Document

Operation and Maintenance and Environmental Monitoring Plan for Solid Waste Management Units 1 and 211-A Remedial Actions for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

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DOE/LX/07-2501&D1
Secondary Document

Operation and Maintenance and Environmental Monitoring Plan for Solid Waste Management Units 1 and 211-A Remedial Actions for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky

Date Issued—March 2024

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

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

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PREFACE

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial actions are being performed at the following U.S. Department of Energy Paducah Site solid waste management units (SWMUs):

- SWMU 1—C-747-C Oil Land Farm—*In situ* source treatment using deep soil mixing with interim land use controls; and

- SWMU 211-A—C-720 TCE Spill Site Northeast—*In situ* source treatment using enhanced *in situ* bioremediation with interim land use controls.

Both remedial actions incorporate *in situ* source treatment with an initial fieldwork phase followed by long-term maintenance and monitoring during which the passive treatment of volatile organic contaminants continues. The operation, maintenance, and monitoring phase to determine the effectiveness and progression of each of the remedial actions and support preparation of the CERCLA-mandated five–year review documents is currently required due to the continued presence of hazardous substances at each SWMU. This operation, maintenance, and environmental monitoring plan identifies the monitoring activities to be continued and discusses the potential need for maintenance of either of the remedial actions until the remedial action goals are attained.

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ACRONYMS

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	contaminants of concern
DHC	*Dehalococcoides* bacteria
DO	dissolved oxygen
DOE	U.S. Department of Energy
DPT	direct push technology
EISB	enhanced *in situ* bioremediation
EPA	U.S. Environmental Protection Agency
EVO	emulsified vegetable oil
FFA	Federal Facility Agreement
KDEP	Kentucky Department for Environmental Protection
LUC	land use control
MW	monitoring well
mZVI	microscale zero-valent iron
N/A	not applicable
NCP	National Contingency Plan
O&M	operation and maintenance
ORP	oxidation-reduction potential
PGDP	Paducah Gaseous Diffusion Plant
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RDR	remedial design report
RGA	Regional Gravel Aquifer
ROD	Record of Decision
SWMU	solid waste management unit
TOC	total organic carbon
UCRS	Upper Continental Recharge System
VOC	volatile organic compound
ZVI	zero-valent iron

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1. INTRODUCTION AND PURPOSE

1.1 SITE NAME AND LOCATION

The U.S. Department of Energy (DOE) Paducah Site is located approximately 10 miles west of Paducah, Kentucky, and 3.5 miles south of the Ohio River in the western part of McCracken County. The Paducah Gaseous Diffusion Plant (PGDP) is located at the DOE Paducah Site (Figure 1). The Paducah Site is situated on approximately 3,556 acres divided as follows:

- Approximately 1,450 acres utilized for site operations;
- Approximately 133 acres in acquired easements; and
- 1,973 acres licensed to the Commonwealth of Kentucky as part of the West Kentucky Wildlife Management Area.

DOE is conducting cleanup activities at PGDP under an environmental management program. Cleanup efforts are necessary to address contamination resulting from past waste-handling and disposal practices at PGDP. The cleanup activities comply with the requirements of the U.S. Environmental Protection Agency (EPA), the Kentucky Department for Environmental Protection (KDEP), and DOE. Past operations and disposal of waste material led to the contamination of the groundwater migrating from PGDP (Figure 2). The Southwest Groundwater Plume refers to an area of groundwater contamination at PGDP in the Regional Gravel Aquifer (RGA), which is south of the Northwest Groundwater Plume and west of the C-400 Cleaning Building. The plume was identified during the Waste Area Grouping 27 Remedial Investigation in 1998 (DOE 1999). DOE conducted a site investigation of the Southwest Plume and documented the information concerning potential source areas in the 2004 *Site Investigation Report for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky* (DOE 2007). Two of the areas ultimately selected for remediation include the following two solid waste management units (SWMUs):

- SWMU 1—C-747-C Oil Land Farm—*In situ* source treatment using deep soil mixing with interim land use controls (LUCs)—Implemented 2014 to 2016; and
- SWMU 211-A—C-720 TCE Spill Site Northeast—*In situ* source treatment using enhanced *in situ* bioremediation (EISB) with interim LUCs—Implemented 2022.

1.2 REGULATORY BACKGROUND

In the fall of 1988, DOE and EPA entered into an Administrative Order by Consent under Sections 104 and 106 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to address the off-site groundwater contamination. On July 16, 1991, EPA and the Commonwealth of Kentucky (also referred to as KDEP) jointly issued permits under the Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendment of 1984. PGDP was placed on the CERCLA National Priorities List in 1994. Pursuant to Section 120 of CERCLA, the PGDP Federal Facility Agreement (FFA) was negotiated and implemented to coordinate the CERCLA remedial action and RCRA corrective action processes into a set of comprehensive requirements for site remediation (EPA 1998). Since 1998, DOE, EPA, and KDEP have been operating under the FFA, with DOE as the lead agency and EPA and KDEP as support agencies providing oversight.

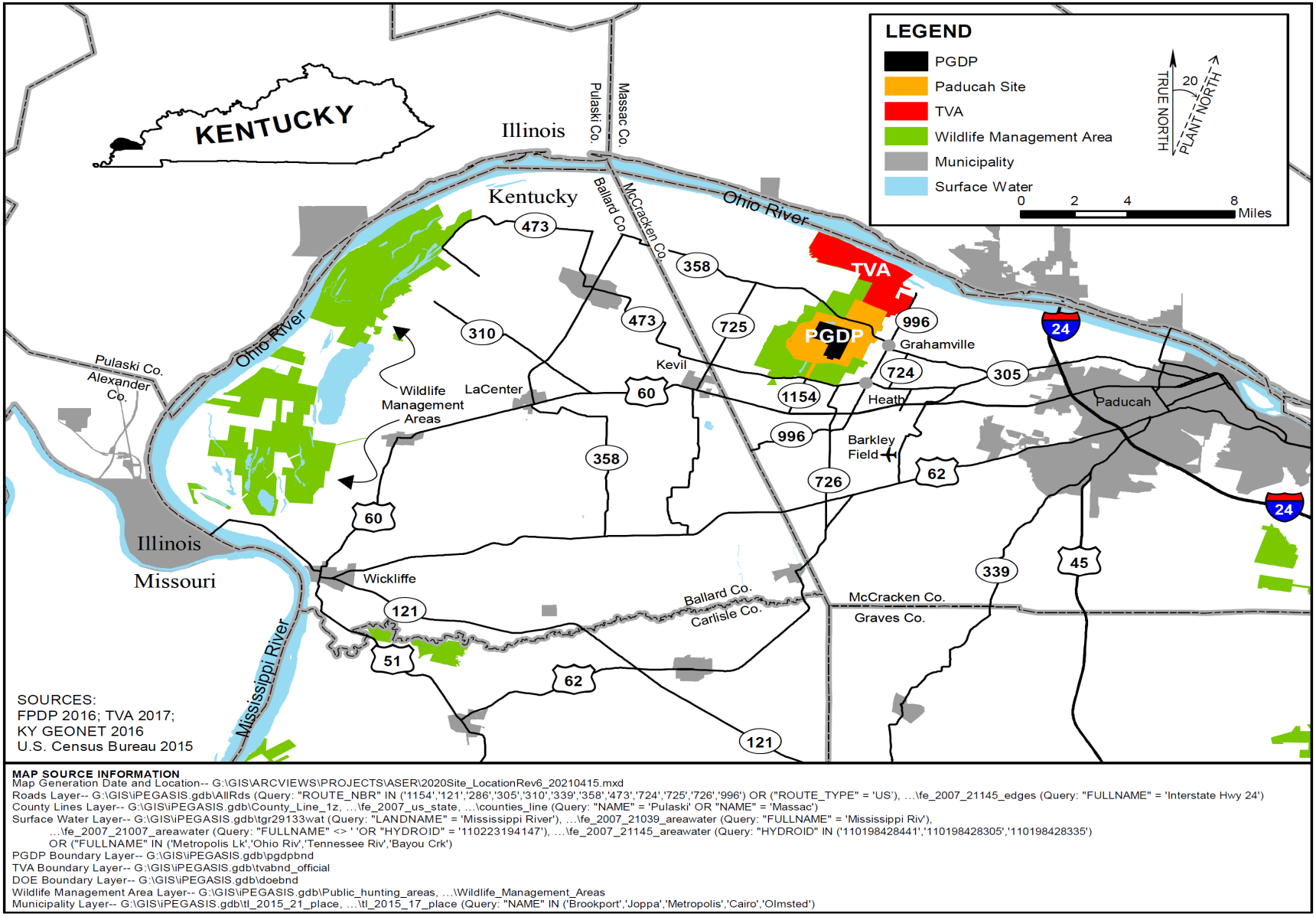

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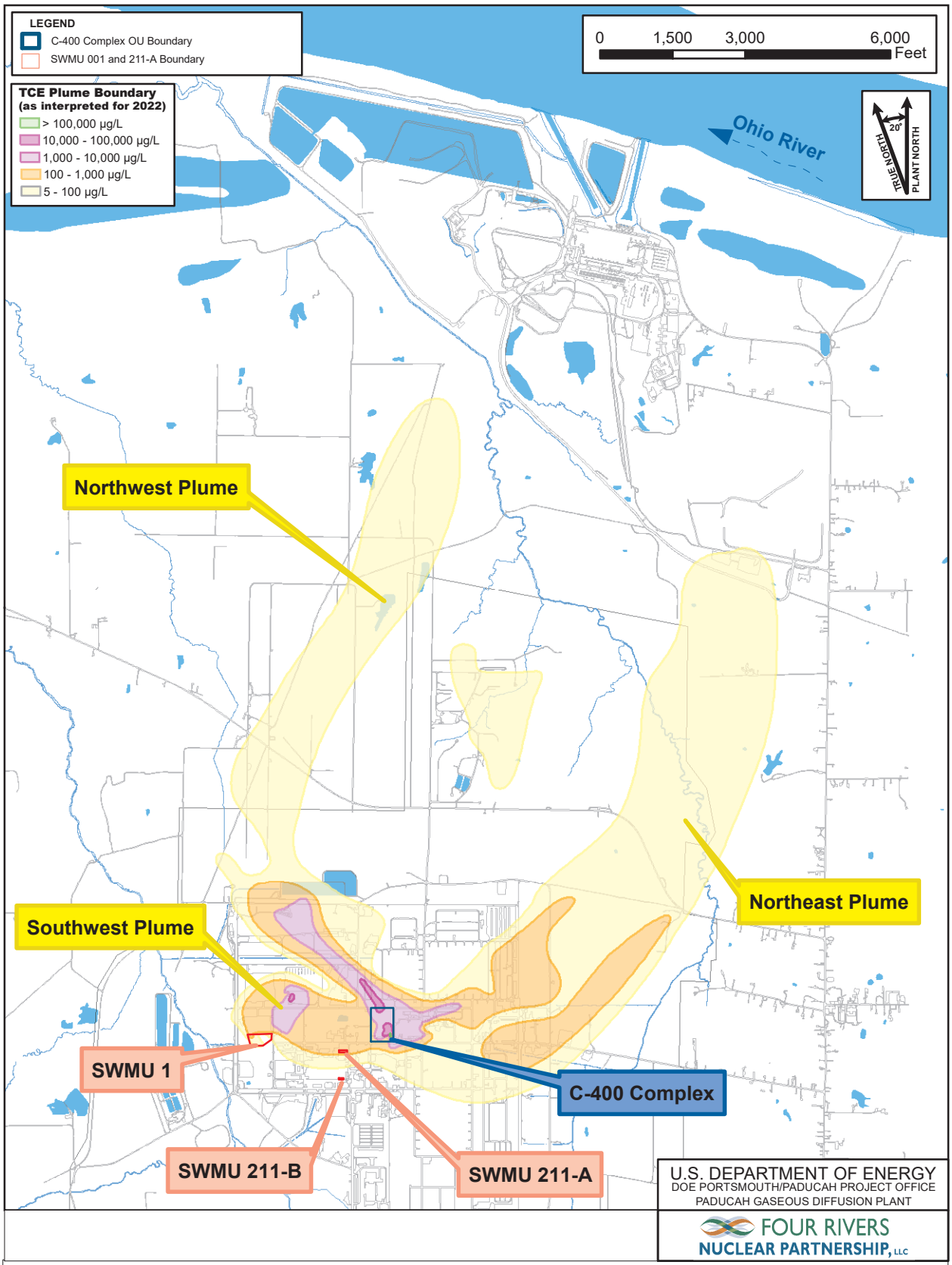
Figure 1. Paducah Gaseous Diffusion Plant Location



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Plume Boundary: G:\GIS\ARCVIEWS\PROJECTS\PLUMES\2022 Plumes(5/9/2023);

Figure 2. Trichloroethene in the Regional Groundwater Aquifer in the Vicinity of the Paducah Gaseous Diffusion Plant, 2022

1.3 CIRCUMSTANCES CREATING THE NEED FOR AN OPERATION, MAINTENANCE, AND ENVIRONMENTAL MONITORING PLAN

Pursuant to the *Record of Decision for Solid Waste Management Units 1, 211-A, 211-B, and Part of 102 Volatile Organic Compound Sources for the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/OR/07-0365&D2/R1 (ROD) signed in March 2012, remedial actions were implemented as listed above in Section 1.1 (DOE 2012).

The remedial actions selected in the ROD were to achieve the following remedial action objectives (RAOs) by removing significant amounts of trichloroethene (TCE) and volatile organic compounds (VOCs) in the subsurface soils. The RAOs for the actions as contained in the ROD include the following (DOE 2012):

1. Treat and/or remove the principal threat waste consistent with the National Contingency Plan (NCP).

2a. Prevent exposure to VOC contamination in the source areas that will cause an unacceptable risk to excavation workers (< 10 ft).

2b. Prevent exposure to non-VOC contamination and residual VOC contamination through interim LUCs within the Southwest Plume source areas (i.e., SWMU 1, SWMU 211-A, SWMU 211-B) pending remedy selection as part of the Soils Operable Unit and the Groundwater Operable Unit.

3. Reduce VOC migration from contaminated subsurface soils in the treatment areas at the oil landfarm and the C-720 northeast and southeast sites so that contaminants migrating from the treatment areas do not result in the exceedance of maximum concentration levels in the underlying RGA groundwater.

Note: A decision concerning a remedy for SWMU 211-B will be made by the FFA parties in conjunction with actions to be taken for the C-720 Maintenance and Storage Building and surrounding area.

SWMU 1—C-747-C Oil Land Farm

The C-747-C Oil Land Farm (SWMU 1) is a facility located outside the Limited Area, near the west fence of the industrial section of PGDP (Figure 2). The facility is bound on the north by the C-745-A Cylinder Storage Yard and by railroad tracks on the east, west, and south. The intersection of Tennessee Avenue and 4th Street lies southeast of SWMU 1.

The remedial action field activities were completed in 2015 for the Southwest Groundwater Plume volatile organic source at SWMU 1, C-747-C Oil Land Farm. The remedial activities included the design, installation, and operation of deep soil mixing with interim LUCs. The soil mixing was supplemented by steam/hot air injection with vapor extraction and zero-valent iron (ZVI) injection, as required by the remedial design report (RDR) (DOE 2013). Following the soil-mixing portion of the remedial action, soils were sampled and monitoring wells (MWs) were installed to continue long-term monitoring for the examination of contaminant trends after active remedy implementation (*in situ* degradation is a follow-on passive remedy component) and to assess progress toward achieving cleanup objectives as prescribed in the ROD. This operation and maintenance (O&M) plan provides the approach for the continued long-term monitoring and inspections to support the development of the required five-year reviews.

SWMU 211-A—C-720 Spill Site Northeast

SWMU 211-A is located in the south-central portion of PGDP. More specifically, the treatment area lies northeast of the C-720 Maintenance and Storage Building. The location of SWMU 211-A is shown in Figure 2. The C-720 building consists of several repair and machine shops, an instrument shop, equipment and material storage areas, and other support operations.

The remedial action for SWMU 211-A included the design and implementation process of EISB with interim LUCs. EISB consists of jet injection hydraulic fracturing using direct push technology (DPT) with sand and ZVI as proppant, and bioamendment and bacterial bioaugmentation injection. Following the completion of the bioaugmentation injection, a network of performance wells (PWs) was installed to monitor the continued effectiveness of EISB. In addition, long-term MWs were installed to assess progress toward achieving cleanup goals, as specified in the ROD (DOE 2012). (Note: *in situ* bioremediation is a passive component of the remedial action.) This O&M plan provides the approach for the continued performance monitoring and long-term monitoring and inspections to support the development of the required five-year reviews.

2. EQUIPMENT STARTUP AND OPERATOR TRAINING

This section describes the equipment required to continue the O&M associated with each of the passive portions of the remedial actions implemented at SWMU 1—C-747-C Oil Land Farm and SWMU 211-A—C-720 Spill Site Northeast. Both of the remedial actions having been implemented became passive remediation systems due to chemical reduction in the presence of ZVI (SWMUs 1 and 211-A) and enhanced bioremediation (SWMU 211-A). To continue to monitor the passive remedial activities, long-term groundwater monitoring networks are present at SWMUs 1 and 211-A, and a performance monitoring network is present within the area being bioremediated at SWMU 211-A. No active field efforts are required for the remedial actions to continue to destruct the chlorinated VOCs present. This section provides a description of equipment present for monitoring each remedial action and its continued treatment of VOC contamination.

2.1 DESCRIPTION OF EQUIPMENT

SWMU 1—C-747-C Oil Land Farm

In situ source treatment using deep soil mixing with interim LUCs was implemented from 2014 to 2016. In 2016, a series of six MWs were installed to become part of the long-term monitoring network for the SWMU 1 remedial action. The six new MWs are completed in the upper RGA. A pre-existing MW is also included in the long-term monitoring network and was completed in the middle RGA. The wells making up that monitoring network are summarized in Table 1. The well locations relative to the SWMU 1 treated/mixed area are shown in Figure 3.

Table 1. SWMU 1 Post-Remedial Monitoring Wells

Monitoring Well Number	Screen Interval, ft bgs	Monitoring Position with Respect to SWMU 1 (Gradient)	Horizon Screened
542	62.75–67.75	Crossgradient	Upper RGA
543	66.25–71.25	Upgradient	Upper RGA
544	62.25–67.25	Upgradient	Upper RGA
545	58.25–63.25	Downgradient	Upper RGA
546	65.0–70.0	Downgradient	Upper RGA
547	63.75–68.75	Downgradient	Upper RGA
161 (existing)	78–83	Downgradient	Middle RGA

Each monitoring well is outfitted with a QED Environmental Systems, Inc., T1200M Micropurge® pump with one-fourth-inch × three-eighths-inch double-bonded tubing or an approved equivalent system.

SWMU 211-A—C-720 TCE Spill Site Northeast

In situ source treatment using EISB was implemented in 2022. Also, in 2022 two MW networks were installed for the SWMU 211-A remedial area. The first was the performance monitoring network. It has a series of 18 MWs, which are arranged in six locations/nests with three wells in each location/nest. See Figure 4 and Table 2 for the performance MW locations. The details associated with the performance monitoring well network are shown in Table 2. All of the performance MWs are located within the area where bioremedial treatment was implemented. Each MW location/nest has one well screened in the middle Upper Continental Recharge System (UCRS) (the shallowest groundwater system), a well screened in the lower UCRS, and one well screened in the upper RGA. The purpose of the network is to allow the collection of data to support an understanding of the bioremedial conditions of the SWMU 211-A subsurface over time. All collected data will support development of appropriate portions of the five-year reviews prepared for the PGDP remedial actions. Each performance monitoring well is outfitted with a QED Environmental Systems, Inc., T1200M Micropurge® pump with one-fourth-inch × three-eighths-inch double-bonded tubing or an approved equivalent system.

The second monitoring network installed was the long-term monitoring network, which includes nine new MWs and one existing MW for a total of 10 MWs. Each monitoring location (Figure 4 and Table 3) includes two wells with one well screened in the upper RGA and the other screened in the middle RGA. The purpose of the network is to support the collection of data to determine the contaminant levels in the RGA as it receives groundwater influx from the UCRS in the area of SWMU 211-A. All collected data will support the development of appropriate portions of the five-year reviews prepared for the PGDP remedial actions. Each long-term MW is outfitted with a QED Environmental Systems, Inc., T1200M Micropurge® pump with one-fourth-inch × three-eighths-inch double-bonded tubing or an approved equivalent system.

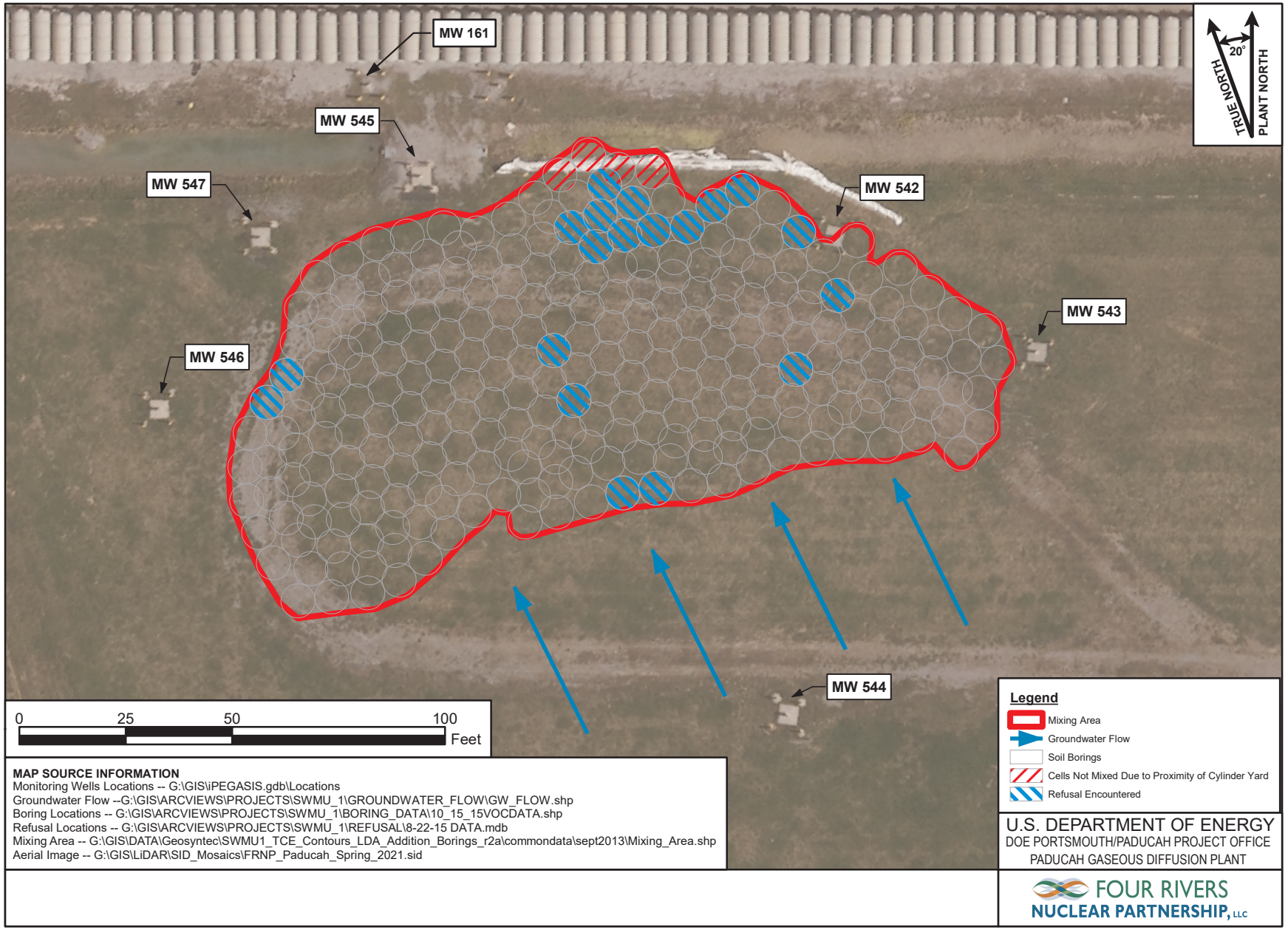

Figure 3. SWMU 1 Post-Treatment Monitoring Well Locations

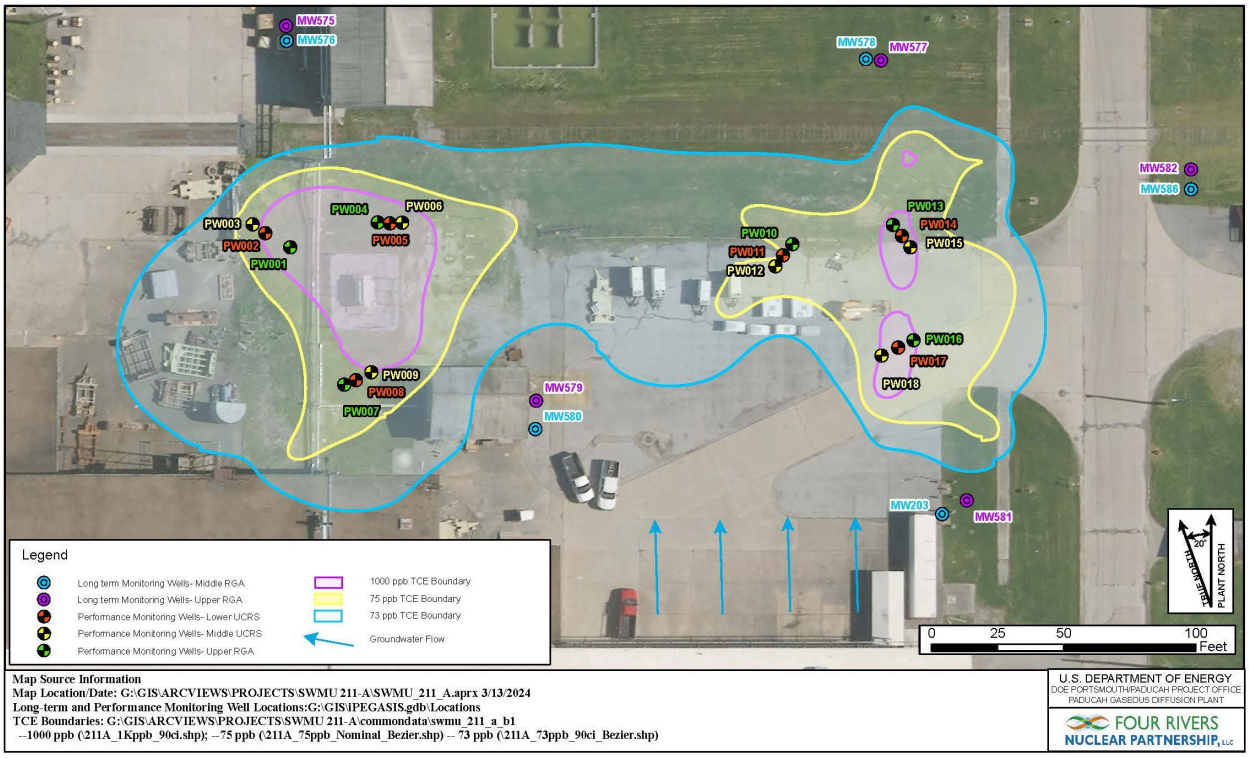

Figure 4. SWMU 211-A Long-Term and Performance Monitoring Well Locations

Table 2. SWMU 211-A Installed Performance Monitoring Wells

Well ID	Horizon Screened	Screened Interval (ft bgs)	Total Depth (ft bgs)	Monitoring Position with Respect to SWMU 211-A (Gradient)
PW001	RGA (Upper)	65–70	71.5	Internal
PW002	UCRS (Lower)	55–60	61.5	Internal
PW003	UCRS (Middle)	45–50	51.5	Internal
PW004	RGA (Upper)	65–70	71.5	Internal
PW005	UCRS (Lower)	55–60	61.5	Internal
PW006	UCRS (Middle)	45–50	51.5	Internal
PW007	RGA (Upper)	65–70	71.5	Internal
PW008	UCRS (Lower)	55–60	61.5	Internal
PW009	UCRS (Middle)	45–50	51.5	Internal
PW010	RGA (Upper)	65–70	71.5	Internal
PW011	UCRS (Lower)	55–60	61.5	Internal
PW012	UCRS (Middle)	45–50	51.5	Internal
PW013	RGA (Upper)	65–70	71.5	Internal
PW014	UCRS (Lower)	55–60	61.5	Internal
PW015	UCRS (Middle)	45–50	51.5	Internal
PW016	RGA (Upper)	65–70	71.5	Internal
PW017	UCRS (Lower)	55–60	61.5	Internal
PW018	UCRS (Middle)	45–50	51.5	Internal

Note: Performance MWs are constructed with a 1.5-ft sump below the screened interval.

Table 3. SWMU 211-A Installed and Existing Long-Term Monitoring Wells

Well ID	Horizon Screened	Screened Interval (ft bgs)	Monitoring Position with Respect to SWMU 211-A (Gradient)
MW575	RGA (Upper)	65–70	Downgradient
MW576	RGA (Middle)	70–75	Downgradient
MW577	RGA (Upper)	65–70	Downgradient
MW578	RGA (Middle)	70–75	Downgradient
MW579	RGA (Upper)	65–70	Upgradient
MW580	RGA (Middle)	70–75	Upgradient
MW581	RGA (Upper)	65–70	Upgradient
MW582	RGA (Upper)	65–70	Crossgradient
MW586	RGA (Middle)	70–75	Crossgradient
MW203	RGA (Middle)	71–76	Upgradient

Note: Long-term MWs are constructed with a 1.5-ft sump below the screened interval. MW203 was constructed with a 0.9-ft sump.

2.2 OPERATOR TRAINING (SWMU 1 AND SWMU 211-A)

As the active fieldwork associated with both of the SWMU 1 and SWMU 211-A remedial actions have been completed as previously discussed, both of the remedial systems are now passive and do not require active remedial operating equipment. The only activities that are performed at both SWMUs include sampling of MWs and inspecting of signs (associated with interim LUCs). The sampling activities are performed by employees consistent with applicable health and safety protocols and applicable sampling procedures.

3. DESCRIPTION OF NORMAL OPERATION, MAINTENANCE, AND ENVIRONMENTAL MONITORING

Neither of the two remedial action technologies that were implemented at SWMU 1 or at SWMU 211-A resulted in the use of a system that would require continuous operations or known standard period/systematic maintenance, such as the one needed for a mechanical operating system. The only field efforts required at either SWMU location are the collection and analysis of groundwater samples with the associated data, and the performance of inspections associated with the interim LUCs. The following subsections describe the required field activities performed to monitor the passive process(es) of the remedial systems to continue treating hazardous substances.

SWMU 1—C-747-C OIL LAND FARM

SWMU 1 remedial action of *in situ* source treatment using deep soil mixing with interim LUCs was implemented from 2014 to 2016. A complete detailed accounting of those field efforts was captured in the *Remedial Action Completion Report for In Situ Source Treatment by Deep Soil Mixing of the Southwest Groundwater Plume Volatile Organic Source at the C-747-C Oil Landfarm (Solid Waste Management Unit 1) at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2405&D2 (DOE 2017). The active portions of the remedial action soil mixing and steam injection with vacuum extraction removed contaminant mass in real time. The soil mixing activities also included the placement of ZVI in the subsurface to provide for the continuing treatment of VOC contamination beyond the soil-mixing period. There are no maintenance activities required for the ZVI. This continued contaminant destruction is passive in nature. Long-term monitoring via the collection of groundwater samples from the

MW network is the only action that has continued beyond the major remedial action components listed above. The continuing normal operations at SWMU 1 are the following:

1. Long-term monitoring, and
2. Interim LUCs inspections.

Environmental monitoring is the periodic collection and laboratory analysis of groundwater samples from the long-term monitoring network. This sampling provides a broader and continuing assessment of dissolved VOC levels in the area of the treated source zone, utilizing the six MWs listed in Table 1. As discussed in the 2012 ROD, long-term monitoring is expected to continue for an extended period of time (68 years) until the RAOs as listed in the ROD and in Section 1 of this document are attained (DOE 2012). The interim LUCs and associated annual inspections also will be performed during this same estimated 68-year time period.

SWMU 211-A—C-720 TCE SPILL SITE NORTHEAST

SWMU 211-A remedial action of *in situ* source treatment using EISB with interim LUCs was implemented in 2022. A detailed accounting of the activities associated with the remedial action is included in the *Interim Remedial Action Completion Report with Postconstruction Report Elements for SWMU 211-A for Volatile Organic Compound Sources to the Southwest Groundwater Plume at the Paducah Gaseous Diffusion Plant, Paducah, Kentucky*, DOE/LX/07-2483&D1 (DOE 2023a). The field activity resulted in the placement of ZVI in the UCRS soils to chemically reduce the VOCs present. The remedial activities also included the placement of bioamendments and bioaugmentation bacteria to setup a bioremediation system to dechlorinate the volatile organic contaminants present. Both the ZVI and bioremediation systems are passive in nature once placed or set-up in the subsurface and do not require maintenance to remain active. The bioremediation system will eventually stop or slow once the bioamendments are exhausted. Those conditions may require the replenishment of the bioamendment and the active bacteria; however, those replenishment activities will be performed under a separate activity and an approved work plan and will not be considered an O&M task, as such (see Section 5.2). The original injection wells remain in place and sealed. Those injections could be used to inject additional amendments to the treatment, if needed. Because the remediation system at SWMU 211-A is passive, there are only three items that are required to monitor the remedial actions progress, and those activities are the following:

1. Performance well monitoring;
2. Long-term well monitoring; and
3. Interim LUCs inspections.

Performance well and long-term well monitoring is the periodic collection and laboratory analysis of groundwater samples from the monitoring networks. This sampling provides a broader and continuing assessment of subsurface conditions at SWMU 211-A. As discussed in the 2012 ROD, the monitoring is expected to continue for an extended period of time (39 years) until the RAOs as listed in the ROD and in Section 1 of this document are attained (DOE 2012). The interim LUCs and associated annual inspections also will be performed during this same estimated 39-year time period.

4. DESCRIPTION OF POTENTIAL OPERATING PROBLEMS

This section describes potential problems associated with the sampling, monitoring, and inspections required at SWMU 1 and SWMU 211-A remedial sites. Because both SWMUs have similar monitoring systems and interim LUC restrictions, the potential problems will be listed in Table 4 with indication if the issue is applicable to both or only one SWMU. The detailed information of any problem will be documented and provided to the project team and subject matter experts to determine if a remedy is available and could it be implemented.

Table 4. Potential Operating Problem Descriptions

Item	Condition	Applicable Remedial System (SWMU 1, 211-A, or Both)	Probable Cause and Potential Resolution(s)
1.	No groundwater or insufficient groundwater present in MW to complete required sampling or obtain a water level.	211-A	PWs and MWs at SWMU 211-A are screened in the UCRS. Groundwater flow in the UCRS is generally vertically downward with little to no horizontal movement. Due to this condition, groundwater may not be available for sampling in the shallow UCRS. Potential resolution is to attempt sampling at another time when there has been recent precipitation.
2.	Groundwater is not produced from the MW pump or water volume is insufficient to sample.	Both	See No. 1 above. Pump or supply tubing may be damaged or require replacement.
3.	White or clear oily residue mixed with groundwater is produced during sampling.	211-A	The vegetable oil that was injected into the UCRS to facilitate bioremedial activity can migrate with the groundwater rather than partitioning to the soil. Analyze the sample “as is” and document the condition on the sample data chain-of-custody form.
4.	LUC signs are missing, severely damaged preventing display, or unreadable.	Both*	Accidental damage, sun fade or weathering. Procure new sign and/or post.

*LUC signs are also present at SWMU 211-B and are inspected at least annually.

5. REMEDIATION MAINTENANCE

5.1 SWMU 1—C-747-C OIL LAND FARM MAINTENANCE

The larger portion of SWMU 1 UCRS contamination was removed during the soil mixing activity. The mixing activity included steam injection and real-time vapor extraction. The final stage of the soil mixing included the placement of ZVI for passive degradation of any remaining UCRS VOC contamination. The ZVI remains in the subsurface to continue to passively degrade VOC contamination. At the completion of field activities, the SWMU surface was returned to natural contours and the long-term MWs were left in place. No internal performance MWs were installed inside the treated area. The SWMU 1 remedial action

has no maintenance activities to be performed to lengthen the passive ZVI activity. Any maintenance that would be needed would have to take the form of a new action. Although SWMU 1 does not have routine maintenance in the remedial action, the SWMU 1 site does get overall routine periodic surface maintenance that includes activities such as mowing the grass, repairing erosional areas as they appear, maintenance of the entrance gravel roadway, replacing of faded and damaged signs, etc.

5.2 SWMU 211-A—C-720 TCE SPILL SITE NORTHEAST ENHANCED *IN SITU* BIOREMEDIATION MAINTENANCE

During the initial EISB implementation at SWMU 211-A, high-pressure jet injections were used to first install sand and microscale zero-valent iron (mZVI)-filled lenses within the UCRS to create zones with enhanced permeability in the subsurface. Injection wells were then installed with screened intervals across the sand-mZVI lenses to enhance the delivery of EISB amendments (i.e., EVO solution and a bacterial consortium) into the UCRS via the sand-mZVI lenses. After EISB is initiated, EVO is consumed by the biodegradation process. If EVO is consumed and further treatment is needed, additional EVO injection events (i.e., maintenance EISB injections) may be necessary to support ongoing bioremediation of the treatment area. If maintenance amendments or bacterial injections are needed, it is planned that they will be performed using the injection wells and sand-mZVI lenses that were installed for the initial EISB injections (DOE 2019a). These replenishment actions will be performed under a separate activity and an approved work plan and will not be considered an O&M task, as such. SWMU 211-A also requires general routine maintenance of the area it occupies. This maintenance, which is performed by the infrastructure subcontractor, includes mowing the inside of the concrete barriers that are being used to protect the 85 injection wells that remain in place for potential use should bioamendments need to be reinjected. Nearby roads and other grounds are also maintained by the infrastructure contractor.

5.2.1 Schedule of Maintenance

The end-goal of the EISB remedial action is to attain the RAOs as listed in Section 1.2. As EVO is consumed by the bacteria prior to attaining project RAOs, then additional EVO may need to be delivered into the UCRS to further continue the process of dechlorinating the VOCs. The need for, and schedule for, EISB maintenance injections will be a decision made at the discretion of the FFA parties along with project team input, and discussions with subject matter experts based on the results of performance monitoring groundwater samples. The performance monitoring plan for groundwater in and around SWMU 211-A is described in Section 2.

Table 5 below identifies parameters that will be considered when determining whether the UCRS may need additional amendments or augmentations to support ongoing EISB. No single parameter should be used for decision making; rather these parameters should be considered collectively by the technical team to assess whether EISB maintenance is needed.

Table 5. SWMU 211-A EISB Monitoring Parameters

Parameter	Consideration for Maintenance EISB Injections
Dissolved Oxygen (DO)	An increasing trend in DO towards aerobic conditions might indicate a change in groundwater geochemistry due to depleted electron donor. Higher DO can potentially decrease the efficiency of EISB.
pH	Ideal pH for EISB is between approximately 5 and 8.
Oxidation-Reduction Potential (ORP)[a]	Increasing ORP, particularly above 0 mV, may indicate need to add electron donor.

Table 5. SWMU 211-A EISB Monitoring Parameters (Continued)

Parameter	Consideration for Maintenance EISB Injections
Total Organic Carbon (TOC)[b]	TOC > 10 mg/L is typically sufficient to support robust bioremediation, although EISB can sometimes persist when TOC is < 10 mg/L (e.g., if m-ZVI is creating hydrogen). Low TOC may indicate a need to add electron donor.
VOC concentration trends and speciation	Slower VOC degradation or a lack of degradation intermediates and/or end products may indicate EISB is stalling.[c]
VOC concentrations in the RGA groundwater	If groundwater in the RGA is meeting standards, then additional EISB in the UCRS may be unnecessary.[d]
KB-1® Plus Population	A decreasing population of DHC bacteria may indicate a poor environment for survival of the bacteria and/or need to add additional bacterial consortium.
Ethene concentration	Cessation of ethene production, following a period of robust EISB, may indicate a slowdown in EISB and need for more electron donor.[c]
Methane concentration	Decreasing methane concentration may indicate more electron donor is needed, since methanogenic bacteria, like DHC, prosper under reducing conditions in the presence of organic carbon.

[a] ORP may be approximated by measuring redox potential (Eh) with a standard hydrogen electrode and applying correction factors.
[b] TOC can be used as a surrogate for available electron donor in groundwater. The 10 mg/L threshold for TOC is an approximate level recommended by GeoSyntec subject matter experts based on experience.
[c] It is recommended that concentration ratios for parent, intermediate and end products of EISB are considered when evaluating the need for EISB maintenance as opposed to only considering absolute concentrations.
[d] RGA contaminants present in upgradient long-term MWs may indicate contaminant migration from other sources.

The factors above should be evaluated using a multiple lines of evidence approach to assess the need for additional EVO injections or other maintenance decisions. For example, if groundwater performance monitoring shows that the bioremediation process has stalled because EVO has been consumed, and further groundwater treatment is needed based on long-term monitoring, then EISB maintenance may be necessary. On the other hand, EISB maintenance may not be necessary, even if EISB has stalled, if monitoring data show RGA groundwater quality has met the remedial action goals. While the injection of additional bacterial consortium is not typically needed after the initial round of bioaugmentation, it might be recommended based on the results of performance monitoring (DOE 2019a).

5.2.2 Process Maintenance Injections

This section describes a general process for maintenance EISB injections in the UCRS using existing injection wells; this process may be modified based on Paducah Site conditions at the time and judgement of the project team. Maintenance EISB injections can be performed via injection wells installed during the initial amendment delivery described in the RDR. The amendment delivery process for EISB maintenance injections will generally follow the process for EVO injections described in the RDR. It is not planned that additional sand-mZVI injections or injection well installation will be needed after the initial remedy implementation.

In some cases, biofouling of the injection well screens may occur after the initial round of EISB injections. Biofouling is typically caused by a residual electron donor in the immediate vicinity of the well screen after injection and can decrease the permeability of the well screen and the sand pack. The EISB injection process that was utilized in the original injections was designed to mitigate biofouling, because injection of EISB amendments were followed by flushing the injection well screen with anaerobic water. If wells are found to be affected by biofouling during an EISB maintenance event [based on attainable flow rates limited to less than 0.5 gal per minute (gpm)], then standard well development

techniques such as surging and pumping will be used. In rare cases, if physical well development is not sufficient to remove biofouling from the well screen, then a chemical additive such as bleach or glycolic acid may be used. The use of these additional compounds and volumes will be discussed in a maintenance work plan that will be developed for review and approval by the FFA managers.

Actual activities and processes to be implemented in any maintenance activity will be documented in a maintenance work plan that will be reviewed and approved by the FFA parties prior to implementation. The actual maintenance details and activities to be performed will be determined based on the project team recommendations utilizing the available data and information of the subsurface conditions present. General steps for maintenance EISB injections are provided below. These steps may be adjusted as needed depending on Paducah Site conditions when a maintenance event is needed (e.g., maintenance EISB injections may be performed only over a portion of the treatment area or in a subset of the injection wells).

- Anaerobic water will be prepared by adding KB-1® Primer or an approved equivalent to water obtained from the on-site potable water supply (expected to be a fire hydrant near SWMU 211-A) to remove DO and residual chlorine and create negative ORP as may be determined by measuring approximate Eh with a standard hydrogen electrode.

- EVO will be mixed with anaerobic water (to create an EVO solution) and the solution injected at the quantities specified in an FFA manager-approved maintenance work plan for each injection well where maintenance EISB injections are going to be performed. Maintenance EISB injections may be needed in all or only in a subset of the SWMU 211-A injection wells.

- EVO solution will be injected into the injection wells that were installed previously during the initial amendment delivery, or into newly installed injection wells that intercept the fracture zone if the previously-installed injection wells are damaged or otherwise unusable. EVO solution should be delivered relatively uniformly, to the degree possible, throughout the target treatment volume.

- It is unlikely that additional KB-1® Plus microbial consortium or an approved equivalent will be needed because bacteria should persist in the treatment zone once populated after the initial amendment delivery event; however, if the FFA managers determine that additional bioaugmentation is warranted, the approach will be documented in an approved maintenance work plan.

- Injection pressures and rates should be kept to the lowest effective levels required to distribute EVO solution through the UCRS.

- Injection pressures within these zones are estimated to range between 15 to 40 lb per square inch (psi). Target injection rates should be between 0.5 to 2 gpm per injection point to facilitate completion of the injection program within a time frame that is practical.

6. REMEDIATION MONITORING/SAMPLING AND ANALYSIS

6.1 SWMU 1—C-747-C OIL LAND FARM LONG-TERM MONITORING SAMPLING AND ANALYSIS

Following the soil mixing activities at SWMU 1, a series of six MWs were installed to become part of the long-term monitoring network for the SWMU 1 remedial action. The six new MWs are completed in the upper RGA. A pre-existing MW is also included in the long-term monitoring network and is completed in

the middle RGA. The wells making up that network along with specific details are shown in Table 1. The well locations relative to the SWMU 1 treated and/or mixed area are shown in Figure 3. Because the remedial action had not attained the RAOs at end of the soil mixing operations, the long-term monitoring network has been periodically sampled to monitor the progress toward attaining the RAOs. The sampling and analysis provides data for the required development of the CERCLA five-year review reports.

The wells are currently sampled on a semiannual schedule. Each MW is currently sampled and analyzed for field parameters and specific VOCs including the following.

- trichloroethene
- 1,1-dichloroethene
- *cis*-1,2-dichloroethene
- *trans*-1,2-dichloroethene
- vinyl chloride

The sampling for SWMU 1 remedial action was initially performed by the crews implementing the project during the first year following the remedial action field implementation (DOE 2014). The continued sampling is being performed semiannually and each sample is analyzed by a DOE Sample Management Office Contract Laboratory and associated quality assurance project plan controls and protocols (DOE 2023b).

The results from the long-term monitoring network are shown in the CERCLA five-year reviews for PGDP remedial actions.

6.2 SWMU 211-A—C-720 TCE SPILL SITE NORTHEAST PERFORMANCE AND LONG-TERM MONITORING SAMPLING AND ANALYSIS AND REPORTING

Performance Monitoring Network—The network has a series of 18 MWs, which are arranged in six locations/nests with three wells in each location (Figure 4). The details associated with the performance monitoring well network are shown in Table 2. All of the performance MWs are located in the area in where bioremedial treatment was implemented. Each location and/or nest has one well screened in the middle UCRS (shallow groundwater system), a well screened in the lower UCRS, and one well screened in the upper RGA. The purpose of the network is to support the collection of data to monitor the bioremedial conditions of the subsurface over time. Collected data will support the development of appropriate portions of the five-year reviews prepared for the PGDP remedial actions.

Long-Term Monitoring Network—The network is composed of 10 MWs in five locations. MWs (well nests) are located in each of the five locations. One well is screened in the upper RGA and one in the middle RGA (Figure 4 and Table 3). Collected data will support the development of appropriate portions of the five-year reviews prepared for the PGDP remedial actions.

The sampling for SWMU 211-A remedial action was initially performed by the crews implementing the project during the first year following the remedial action field implementation (DOE 2019b, DOE 2023a). The continued sampling is being performed semiannually and each sample is analyzed by a DOE Sample Management Office Contract Laboratory and associated quality assurance project plan controls and protocols as shown in Table 6 (DOE 2019c, DOE 2023b).

The results from the long-term and performance monitoring networks are shown in the CERCLA five-year reviews for PGDP remedial actions. Interim informal data summaries may also be provided to the FFA parties as data becomes available.

Table 6. SWMU 211-A Post-Injection Sampling and Analysis Plan

Sample Location	Geologic Unit	Screened Interval [ft below ground surface (bgs)]	Sample Depth (ft bgs)	Years 1–5 after EISB Implementation		Years > 5 after EISB Implementation			
				Semiannual Years 1–5 after EISB Implementation		Semiannual Years > 5 after EISB Implementation		Annual Years > 5 after EISB Implementation	
				Water Level	Sample Analysis	Water Level	Sample Analysis	Water Level	Sample Analysis
Performance Monitoring Wells									
PW001	RGA (Upper)	65–70	67	x	8260C, RSK-175, TOC + DUP	x	8260C, RSK-175, TOC + DUP	Not Applicable (N/A)	N/A
PW002	UCRS (Lower)	55–-60	57	x	8260C, RSK-175, TOC, Dhc + DUP	x	8260C, RSK-175, TOC, Dhc + DUP	N/A	N/A
PW003	UCRS (Middle)	45–-50	47	x	8260C, RSK-175, TOC, Dhc	x	8260C, RSK-175, TOC, Dhc	N/A	N/A
PW004	RGA (Upper)	65–-70	67	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW005	UCRS (Lower)	55–-60	57	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW006	UCRS (Middle)	45–-50	47	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW007	RGA (Upper)	65–-70	67	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW008	UCRS (Lower)	55–-60	57	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW009	UCRS (Middle)	45–-50	47	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW010	RGA (Upper)	65–-70	67	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW011	UCRS (Lower)	55–-60	57	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW012	UCRS (Middle)	45–-50	47	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW013	RGA (Upper)	65–-70	67	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW014	UCRS (Lower)	55–-60	57	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW015	UCRS (Middle)	45–-50	47	x	8260C, RSK-175, TOC	x	8260C, RSK-175, TOC	N/A	N/A
PW016	RGA (Upper)	65–-70	67	x	8260C, RSK-175, TOC + MS/MSD	x	8260C, RSK-175, TOC + MS/MSD	N/A	N/A
PW017	UCRS (Lower)	55–-60	57	x	8260C, RSK-175, TOC, Dhc	x	8260C, RSK-175, TOC, Dhc	N/A	N/A
PW018	UCRS (Middle)	45–-50	47	x	8260C, RSK-175, TOC, Dhc	x	8260C, RSK-175, TOC, Dhc	N/A	N/A

Table 7. SWMU 211-A Post-Injection Sampling and Analysis Pl (Continued)

Sample Location	Geologic Unit	Screened Interval (ft bgs)	Sample Depth (ft bgs)	Years 1–5 after EISB Implementation		Years > 5 after EISB Implementation			
				Semiannual Years 1–5 after EISB Implementation		Semiannual Years > 5 after EISB Implementation		Annual Years > 5 after EISB Implementation	
				Water Level	Sample Analysis	Water Level	Sample Analysis	Water Level	Sample Analysis
Long-Term Monitoring Wells									
MW575	RGA (Upper)	65–-70	67	x	8260C** + DUP	N/A	N/A	x	8260C** + DUP
MW576	RGA (Middle)	70–-75	72	x	8260C**	N/A	N/A	x	8260C**
MW577	RGA (Upper)	65–-70	67	x	8260C**	N/A	N/A	x	8260C**
MW578	RGA (Middle)	70–-75	72	x	8260C** + MS/MSD	N/A	N/A	x	8260C** + MS/MSD
MW579	RGA (Upper)	65–-70	67	x	8260C**	N/A	N/A	x	8260C**
MW580	RGA (Middle)	70–75	72	x	8260C**	N/A	N/A	x	8260C**
MW581	RGA (Upper)	65–70	67	x	8260C**	N/A	N/A	x	8260C**
MW203	RGA (Middle)	71–76	73	x	8260C**	N/A	N/A	x	8260C**
MW582	RGA (Upper)	65-–0	67	x	8260C**	N/A	N/A	x	8260C**
MW586	RGA (Middle)	70-–5	72	x	8260C**	N/A	N/A	x	8260C**
Quality Control Samples									
Trip Blank	N/A	N/A	N/A	N/A	8260C	N/A	8260C	N/A	N/A

NOTES:
8260C = VOCs by Method 8260C or current applicable method (gas chromatograph/mass spectrometer), laboratory reports the full list of VOCs.
8260C** = VOCs by Method 8260C or current applicable method (gas chromatograph/mass spectrometer), laboratory reports concentrations for only TCE, *cis*-1,2-DCE, *trans*-1,2-DCE, 1,1-DCE, and vinyl chloride.
RSK-175 = analysis for dissolved hydrocarbon gasses (ethene, ethane, and methane) by Method RSK SOP 175 Modified.
Dhc = analysis for presence of *dehalococcoides* bacteria
DUP = duplicates of the analyses at this well will be performed
MS/MSD = Laboratory matrix spike and laboratory matrix spike duplicate performed for this sample
Method 8260D may be substituted for Method 8260C.

6.3 MONITORING WELL INSPECTIONS AND WELL MAINTENANCE (SWMU 1 AND SWMU 211-A)

Performance and long-term MWs will be visually inspected for damage as outlined in DOE Prime Contractor procedures in place at the time of sampling. Damage will be documented on the sampling chain-of-custody or sample data form (or other field form as appropriate) and photographs can be taken if needed. The field staff performing the inspection may investigate the well damage and stabilize the well to prevent further damage or impacts to groundwater if the conditions are safe to do so. A report of the damage will be provided to the project manager so repairs can be assessed.

MWs located at both SWMU 1 and SWMU 211-A are susceptible to internal biological growth due to the mixing, injecting, and general intrusive subsurface activities that have occurred in the areas remediated. Mechanical issues also may occur in the screens and casings making up the wells. As these items are identified, the wells will be rehabilitated as needed according to contractor procedures.

6.4 WATER LEVEL ANALYSIS (SWMU 1 AND SWMU 211-A)

Water levels are collected each time the wells are sampled as part of the field parameters measured prior to sampling. The water level measurements collected are included in the well data and entered into Oak Ridge Environmental Information System with other data and utilized as needed for PGDP groundwater flow analysis and development of CERCLA five-year reviews.

6.5 INTERIM LAND USE CONTROL INSPECTIONS (SWMU 1, SWMU 211-A, AND SWMU 211-B)

The ROD included the placement of interim LUCs on SWMU 1, 211-A, and 211-B. The interim LUCs included warning signs to provide notice of environmental contamination present at SWMU 1, SWMU 211-A, and 211-B. The warning signs state the following:

WARNING: CONTAMINATED AREA
Hazardous Substances in Soil and Groundwater
Authorized Access Only
Contact: [Insert Phone Number]

The interim LUCs include notification signs and the excavation/penetration permit program for PGDP intrusive activities. The signs are mounted to a concrete base and a pole for stability. The interim LUCs will be inspected at least annually until a final remedy is selected as part of a subsequent operable unit that addresses the relevant media.

7. RECORDS AND REPORTING

7.1 PROJECT RECORDS

Records that are generated and filed include interim LUC inspection and sampling chain-of-custody forms. Forms are completed consistent with the applicable procedure.

7.2 REPORTING REQUIREMENTS

The inspections resulting from the interim LUCs and the MW sampling and associated laboratory results are reported to EPA and KDEP in a PGDP synchronized Five-Year Review for Remedial Action at the Paducah Gaseous Diffusion Plant report (DOE 2014 and DOE 2019b). Interim informal data summaries may also be provided to the FFA parties as data becomes available.

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