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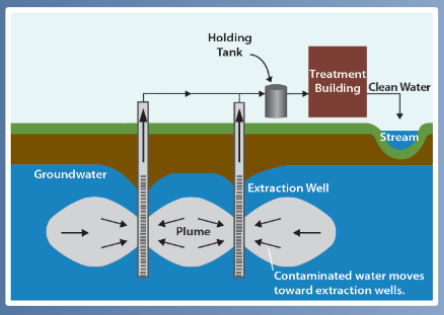
United States Environmental Protection Agency

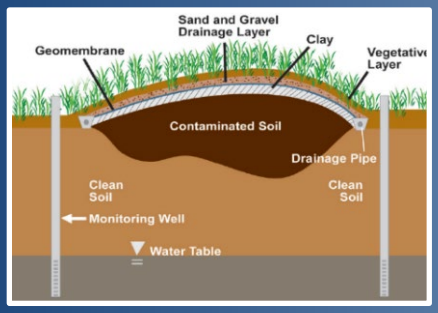
Superfund Remedy Report

18th Edition

Remedy Selection



Conceptual Design



Implementation

Completion and Reuse

Cover photo credits:

Upper left: EPA Community Guide to Pump and Treat.
https://semspub.epa.gov/src/document/HQ/401617

Upper center: New groundwater treatment plant at Chem-Fab Superfund Site.
https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.photovideoaudio&id=0300563

Upper right: The Coeur d'Alene River at Bunker Hill Superfund Site.
https://www.epa.gov/superfund/superfund-success-stories-epa-region-10

Lower left: EPA Community Guide to Capping.
https://semspub.epa.gov/src/document/HQ/401585

Lower center: Stainless steel gas collection piping in OU3 cap at Standard Chlorine of Delaware, Inc.
https://cumulis.epa.gov/supercpad/SiteProfiles/index.cfm?fuseaction=second.photovideoaudio&id=0300058

Lower right: Solar panels at the Brick Township Landfill Superfund Site. https://semspub.epa.gov/src/document/02/372924

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A portable document format version of the *Superfund Remedy Report (SRR) 18th Edition* is available for viewing or downloading from https://www.epa.gov/remedytech/superfund-remedy-report. The data that form the basis of the analyses contained in the *SRR 18th Edition* can be found at https://www.epa.gov/superfund/superfund-data-and-reports by downloading *Contaminant of Concern Data for Decision Documents by Media, FY 1981–2023* and *Remedy Component Data for Decision Documents by Media, FY 1981–2023*.

Acronyms and Abbreviations

AC	Activated carbon
ASR	Annual Status Report
BTEX	Benzene, toluene, ethyl-benzene, xylenes
CAD	Contained aquatic disposal
CDF	Confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	Contaminant of concern
DNAPL	Dense non-aqueous phase liquid
EMNR	Enhanced monitored natural recovery
EPA	U.S. Environmental Protection Agency
ESD	Explanation of Significant Differences
ESTCP	Environmental Security Technology Certification Program
ET	Evapotranspiration
FRTR	Federal Remediation Technologies Roundtable
FY	Fiscal year
GAC	Granular activated carbon
IC	Institutional control
ISCO	In situ chemical oxidation
ISCR	In situ chemical reduction
ISTT	In situ thermal treatment
ITRC	Interstate Technology & Regulatory Council
LNAPL	Light non-aqueous phase liquid
MNA	Monitored natural attenuation
MNR	Monitored natural recovery
MPE	Multi-phase extraction
NAPL	Non-aqueous phase liquid
NPL	National Priorities List
nZVI	Nanoscale zero valent iron
OLEM	Office of Land and Emergency Management
OSWER	Office of Solid Waste and Emergency Response
P&T	Pump and treat
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
PFAS	per- and polyfluoroalkyl substances
PFOA	perfluorooctanoic acid
PFOS	perfluorooctanesulfonic acid
PRB	Permeable reactive barrier
ROD	Record of Decision
S/S	Solidification/stabilization
SA	Superfund Alternative
SRR	Superfund Remedy Report
SVE	Soil vapor extraction
SVOC	Semivolatile organic compound
TCE	Trichloroethylene
VEB	Vertical engineered barrier
VOC	Volatile organic compound
ZVI	Zero valent iron

I. Purpose and Introduction

What's New in This Edition?

- Analysis of 295 decision document actions for FYs 2021 to 2023
- Discussion of in situ carbon amendments
- Inclusion of PFAS as a detailed contaminant group

The U.S. Environmental Protection Agency's (EPA) Office of Superfund Remediation and Technology Innovation prepared this *Superfund Remedy Report (SRR) 18th Edition* to share analyses of remediation technologies selected to address contamination at Superfund sites. EPA is particularly interested in documenting and disseminating information on treatment technologies to advance its mission of protecting human health and the environment. The report focuses on treatment as the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) establishes a statutory preference for treatment.[1]

The remedy and site information provided in this report informs stakeholders in Superfund communities about the program's remedy decisions and helps federal, state, and tribal remediation professionals select future remedies. Analyzing the trends in remedy decisions provides an indication of the future demand for remedial technologies, which helps technology developers and consulting and engineering firms evaluate cleanup markets. The trends also indicate program needs for expanded technical information and support related to specific technologies or site cleanup challenges.

Selected remedial actions for Superfund sites, including National Priorities List (NPL) and Superfund Alternative (SA) approach sites, are recorded in a decision document, such as a Record of Decision (ROD), ROD Amendment, or Explanation of Significant Differences (ESD). The *SRR 18th Edition* builds upon the *SRR 17th Edition* (data through fiscal year [FY] 2020) and adds remedy and contaminant information from decision documents issued during FYs 2021, 2022, and 2023. EPA used decision document data from the Superfund Enterprise Management System as of March 2024 to compile information about remedy selection for all years (FYs 1981 to 2023) with a focus on the most recent three years (FYs 2021, 2022, and 2023).[2] The data used include remedies selected in decision documents (RODs, ROD Amendments, and select ESDs). Only ESDs with an addition or change to a remedy component or a contaminant of concern (COC) were included in the remedy and COC analyses, respectively. Note that this report includes only remedial actions and does not include removal actions. Activities conducted as part of a removal action are only captured by the remedial program if the action becomes part of the selected remedy included in a decision document (ROD, ROD Amendment, or ESD). For example, if a pump and treat (P&T) system is installed as part of a removal action and then identified as part of the subsequent remedial action, it would be considered a remedial action and included in this report.

II. Scope of This Report

This report discusses decision documents for final and deleted NPL sites that have had at least one decision document issued by the end of FY 2023. In addition, the SRR analysis includes decision

[1] Comprehensive Environmental Response, Compensation, and Liability Act of 1980 and the amendments made by subsequent enactments (42 U.S.C. 9601-9675).

[2] The data that form the basis for the analyses contained in the *SRR 18th Edition* are available for download at https://www.epa.gov/superfund/superfund-data-and-reports.

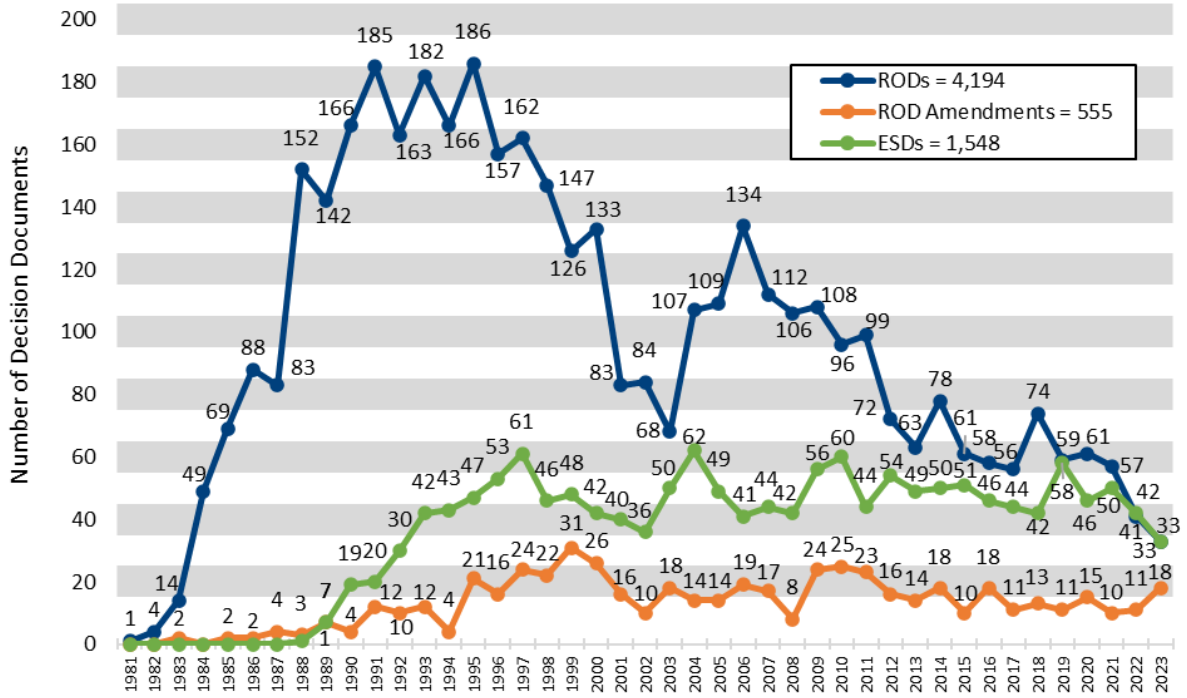
documents that selected remedies to address contamination at sites with SA approach agreements as of March 2024.[3]

There are 1,680 sites that have at least one decision document, which form the basis for the SRR and its analyses. Because some decision documents track decisions for more than one operable unit, those decisions are counted as separate actions for each operable unit. The data in Figure 1 and throughout this report count each decision document action separately. For purposes of this report, the number of decision documents refers to the number of decision document actions.

A total of 6,297 decision documents, consisting of 4,194 RODs, 555 ROD amendments, and 1,548 ESDs have been issued from FY 1981 through FY 2023 (Figure 1). More than 36 percent of decision documents are for federal facilities.

As shown below in Figure 1, the overall number of decision documents continues to decrease for the Superfund program. The total number of decision documents per FY peaked in 1995 at 254. However, during the most recent two years (2022 and 2023), the total number of documents decreased to below 100, to 94 and 84, respectively. FY 2022 also marked the first year that the number of ESDs exceeded the number of RODs issued with 42 and 41, respectively.

Figure 1: Decision Document Actions per Fiscal Year (FY 1981–2023)



[3] "One of EPA's non-NPL Superfund pathways is referred to as the Superfund Alternative (SA) approach. The SA approach uses the same process and standards for investigation and cleanup as sites on the NPL. Sites using the SA approach are not eligible for federal remedial cleanup funds. Cleanup funding for sites with SA approach agreements is provided by the potentially responsible parties." (EPA, 2008b). To be considered an official SA approach site, there needs to be a Superfund Alternative approach agreement, per Office of Enforcement and Compliance Assurance policy (see: https://www.epa.gov/enforcement/superfund-alternative-approach). The list of sites with an SA approach agreement is as of April 24, 2024.

Although all ESDs are shown in Figure 1, only ESDs with a remedy component are included in the subsequent remedy analysis (778 of 1,548).

This report evaluates remedy selection trends historically and cumulatively through FY 2023. It also provides a more detailed analysis of the decision documents issued in FYs 2021, 2022, and 2023. For FYs 2021 to 2023, 198 of the 295 decision documents have remedy components and are included in this report's remedy analysis.

III. Overview of Remedy Selection

The SRR remedy analysis distinguishes between remediation of source materials and groundwater. EPA defines "source material" as "material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contamination to ground water, to surface water, to air, or acts as a source for direct exposure" (EPA, 1991a). This includes contaminated soil, sludge, sediment, solid waste, debris, drummed waste, leachate, and any non-aqueous phase liquid (NAPL), both light (LNAPL) and dense (DNAPL). EPA defines groundwater as non-source material.

This report includes remedies selected in the Superfund remedial program, grouped into major categories including treatment, containment, and other remedial components indicated by the green bars in Table 1. The table describes remedies related to source, groundwater, or vapor intrusion based on the media addressed.

Table 1: Summary of Remedy Categories

Source Material
Treatment
· Alters the composition of a hazardous substance or pollutant or contaminant through chemical, biological, or physical means to reduce toxicity, mobility, or volume of contaminated source media[4] · May be either in situ or ex situ · Examples include chemical treatment and thermal treatment
On-site Containment
· Examples include the use of caps, liners, covers, and landfilling on site
Off-site Disposal
· Includes excavation and disposal at an off-site facility with or without treatment, as required by regulation
Monitored Natural Attenuation (MNA)
· Relies on natural processes to reduce mass, toxicity, mobility, volume, or concentration of contaminants · May include physical, chemical, and biological processes
Monitored Natural Recovery (MNR)
· Relies on natural processes to reduce risk from sediments · May include physical, chemical, and biological processes
Enhanced Monitored Natural Recovery (EMNR)
· Combines natural recovery with an engineered approach for sediments · Typically includes placing a thin layer of clean sediment to accelerate the recovery process
Institutional Controls (ICs)
· Non-engineered instruments, such as administrative and legal controls, that help minimize the potential for human exposure to contamination and protect the integrity of the remedy · Examples for source media include restrictive covenants and easements

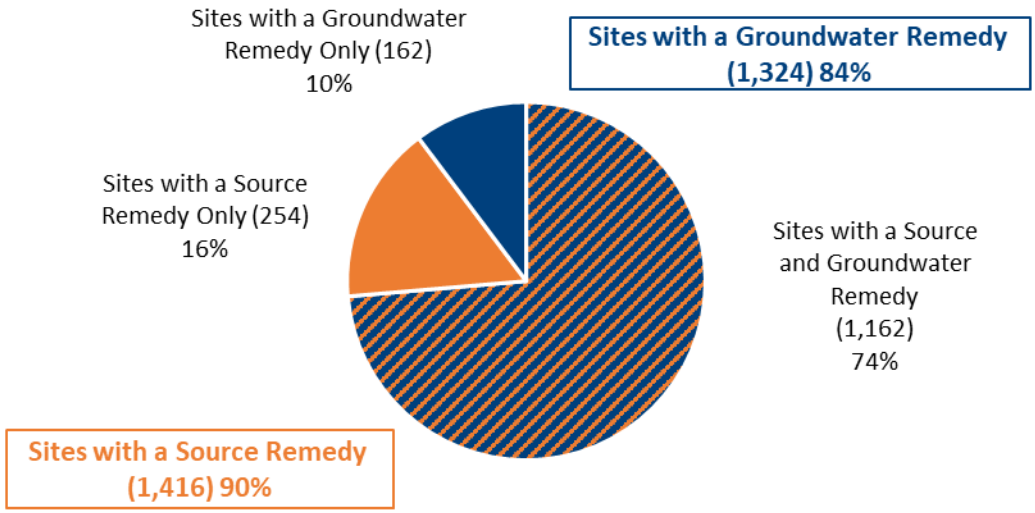
[4] Code of Federal Regulations, title 40, sec 300.5. https://www.gpo.gov/fdsys/pkg/CFR-2001-title40-vol24/pdf/CFR-2001-title40-vol24-sec300-5.pdf.

Other
· Source remedies that do not fall into the categories of source treatment, on-site containment, off-site disposal, MNA, MNR, EMNR, or ICs · Examples include wetlands replacement and habitat restoration
Groundwater
In Situ Treatment
· Treats groundwater in place without extraction from an aquifer · Examples include in situ chemical oxidation and in situ bioremediation
Pump and Treat (P&T)
· Pumps groundwater from a well or trench, followed by aboveground treatment · Examples of aboveground treatment include air stripping and granular activated carbon
Monitored Natural Attenuation (MNA)
· Relies on natural processes to reduce mass, toxicity, mobility, volume, or concentration of contaminants · May include physical, chemical, and biological processes
Vertical Engineered Barrier (VEB)
· Contains groundwater using a vertical, engineered, subsurface, impermeable barrier
Institutional Controls (ICs)
· Non-engineered instruments, such as administrative and legal controls, that help minimize the potential for human exposure to contamination and protect the integrity of the remedy · Examples for groundwater include drilling restrictions and water supply use restrictions
Alternative Water Supply
· Examples include installing new water supply wells, providing bottled water, or extending a municipal water supply
Other
· Groundwater remedies that do not fall into the categories of in situ treatment, P&T, MNA, VEB, ICs, or alternative water supply · Examples include drainage/erosion control and water table adjustment
Vapor Intrusion
Mitigation
· Mitigates soil gas or indoor air to reduce exposure to vapor contamination in buildings · Examples include active depressurization technologies and passive barriers
Institutional Controls (ICs)
· Non-engineered instruments, such as administrative and legal controls, that help minimize the potential for human exposure to contamination and protect the integrity of the remedy · Examples for vapor intrusion include deed restrictions requiring vapor intrusion mitigation for new buildings developed at the site

Summary of Sites

Of the 1,680 Superfund sites with decision documents, remedies were selected at 1,578 sites, and no action or no further action was specified as the only action at 102 sites. As shown below, of the 1,578 sites with remedies, source (soil, sediment, solid waste, debris, buildings/structures, sludge, leachate, liquid waste, and NAPL) and groundwater are addressed at 90 percent (1,416 sites) and 84 percent (1,324 sites), respectively (Figure 2). Nearly three-quarters (74 percent) have remedies that address both source and groundwater. This figure highlights that Superfund sites are complex and typically have multiple media and multiple remedies. Comparing this figure to data through FY 2002 (recalculated from Figure 1 in the *Treatment Technologies for Site Cleanup: Annual Status Report [ASR] 11th Edition* based on an updated analysis approach) shows the number of sites with a source remedy has increased slightly from 83 to 90 percent over the last 20 years.

Figure 2: Superfund Sites Addressing Source and Groundwater Media (FY 1981–2023)



- Number of Superfund sites with a remedy selected in a decision document = 1,578.
- Does not include 102 sites with only no action or no further action selected in all decision documents.

Sites may have only a groundwater remedy selected for a variety reasons, including (1) groundwater is being addressed first and a source action has not yet been selected, (2) source was addressed during a removal action and groundwater is being addressed under a remedial action, and (3) the site is a "groundwater only" site, such as a municipal well field in an industrial area where the source of contamination is being addressed by other Superfund sites or programs.

EPA further analyzed the media addressed by selected remedies at Superfund sites (Table 2). Groundwater is addressed most frequently (84 percent), followed by soil (81 percent), sediments (31 percent), and solid waste (30 percent). NAPL is considered a source medium when it contributes to groundwater contamination. However, EPA does not have complete data on its presence at Superfund sites. NAPL is often difficult to locate during a site investigation, and there may not be direct evidence of its presence at the time EPA signs a decision document. In addition, EPA has tracked NAPL as a separate medium when reviewing remedy decisions only since FY 2012. For these reasons, NAPL is not included in Table 2.

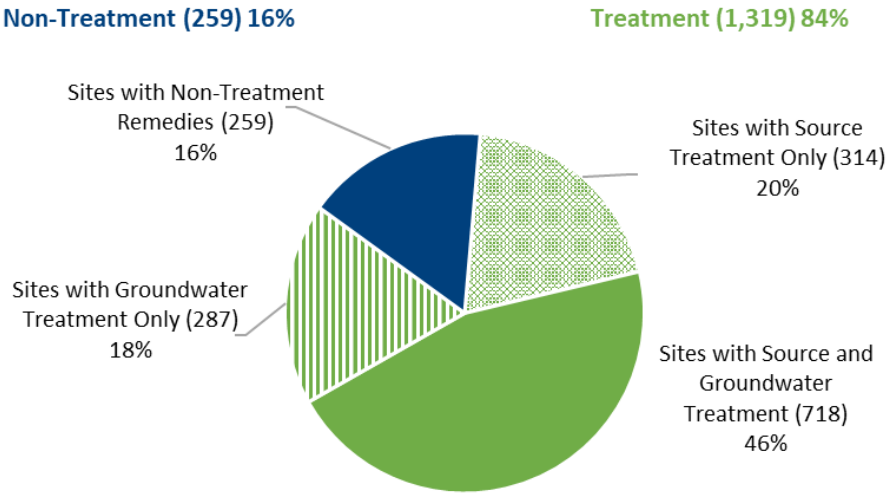
Table 2: Media Addressed at Superfund Sites with Remedies (FY 1981–2023)

Media		Number of Sites	Percentage of Sites
Groundwater		1,324	84%
Source (1,416 Sites) 90%	Soil	1,286	81%
	Sediment	485	31%
	Solid Waste	467	30%
	Debris	224	14%
	Buildings/Structures	191	12%
	Sludge	159	10%
	Leachate	139	9%
	Liquid Waste	117	7%

- Number of Superfund sites with a remedy selected in a decision document = 1,578.
- Number of Superfund sites with a selected remedy for NAPL in a decision document since FY 2012 = 148. As noted, this number does not represent the total number of Superfund sites with NAPL contamination.

Figure 3 shows that 84 percent of Superfund sites with remedies (1,319 of 1,578) had at least one treatment remedy selected for source, groundwater, or both. This figure demonstrates that remedy selection is generally consistent with CERCLA's preference for treatment. When comparing data through FY 2002 (recalculated from Figure 1 in the *ASR 11th Edition* based on an updated analysis approach), this figure shows the number of sites with a treatment remedy has increased from 74 to 84 percent over the last 20 years.

Figure 3: Remedy Selection at Superfund Sites (FY 1981–2023)



- Number of Superfund sites with a remedy selected in a decision document = 1,578.
- Does not include 102 sites with only no action or no further action selected in all decision documents.
- Non-treatment remedies include on-site containment, off-site disposal, monitored natural attenuation, monitored natural recovery, enhanced monitored natural recovery, vertical engineered barriers, institutional controls, alternative water supply, vapor intrusion mitigation, and other remedies described in Table 1.

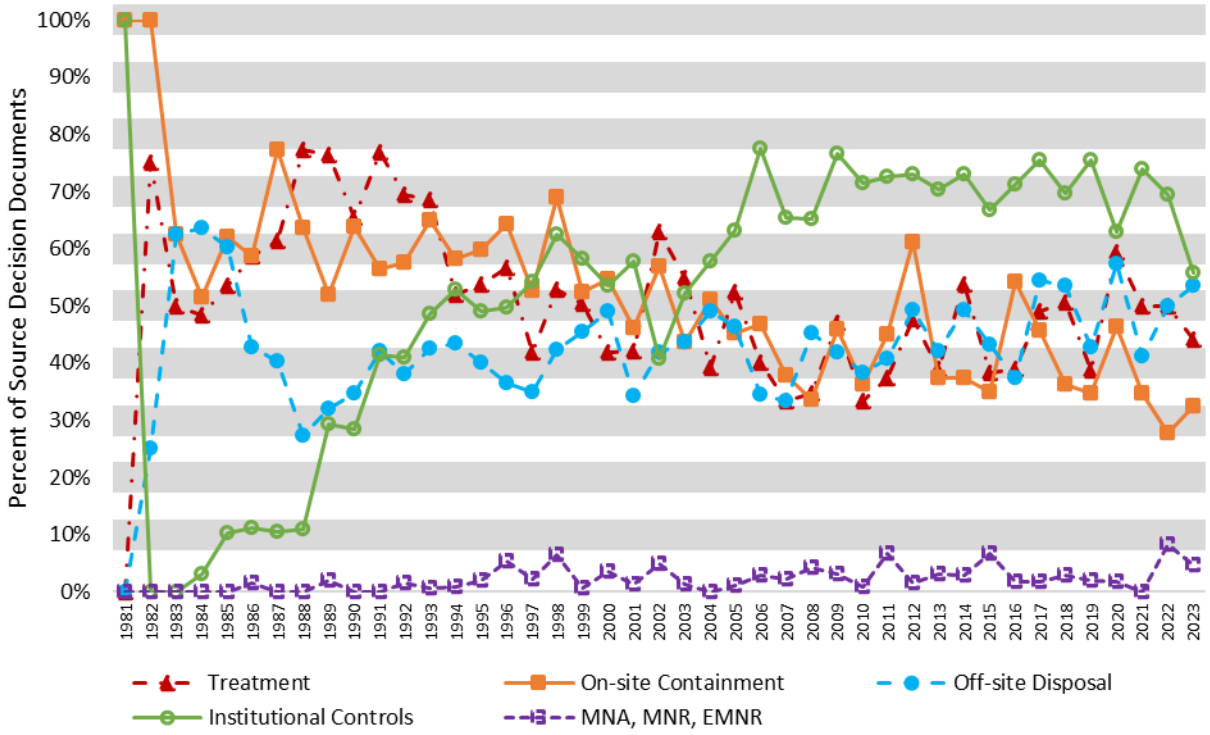
Trends in Decision Documents

Overall, 4,726 of the 6,297 decision documents issued from FYs 1981 to 2023 have remedial components and are included in the remedy analysis. Of those, EPA evaluated 3,534 decision

documents with source remedies at 1,416 sites and 2,783 decision documents with groundwater remedies at 1,324 sites.

Figure 4 shows the selection of treatment, on-site containment, and off-site disposal has remained relatively stable on average for source remedies over the last 20 years, generally ranging from 35 to 55 percent since 2000 for all three remedy types. IC remedies increased in the early 2000s before also leveling off to become stable. The selection of MNA, MNR, and EMNR as source remedies continues to be low. Further analysis determined two-thirds of all source documents selected multiple remedy types, which include a combination of treatment, on-site containment, off-site disposal, ICs, MNA/MNR/EMNR, and other remedial components.

Figure 4: Selection Trends for Decision Documents with Source Remedies (FY 1981–2023)



- Number of source decision documents = 3,534.
- Decision documents are included in more than one remedy category when they select multiple remedies.

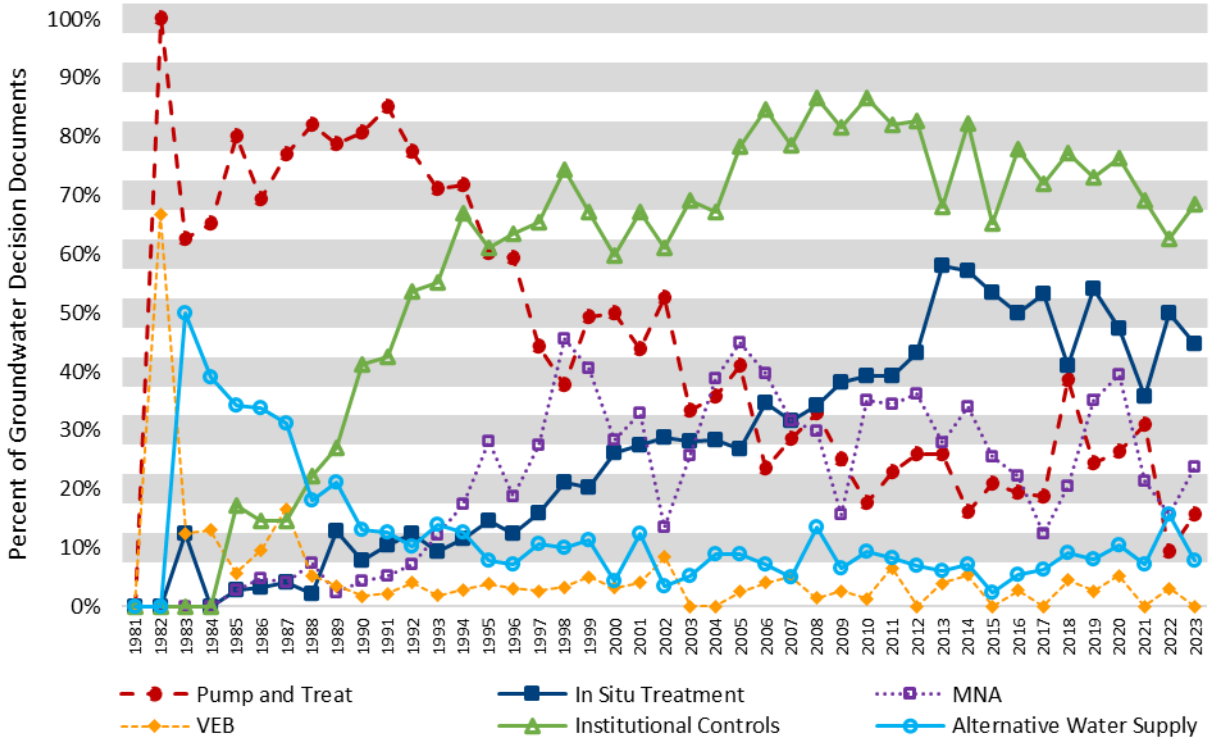
While the selection of on-site containment has been trending slightly downward in recent years and off-site disposal has been trending slightly upward, these remedies continue to be selected frequently for Superfund sites. Both are often part of a larger site strategy that includes a combination of remedies. Additionally, details of the remedies selected offer perspective regarding the scale of each remedy type beyond the count of how often each remedy was selected. For example, a closer look at on-site containment and off-site disposal remedies for soil in FY 2023 decision documents showed that while off-site disposal was selected more frequently, a higher volume of soil was managed using on-site containment. The smaller volumes of soil sent for off-site disposal were often principal threat wastes or hotspots. Larger volumes of soil are often contained on site because of challenges with moving large volumes of contaminated media, such as increased traffic and risk to neighboring communities and the environment, lack of nearby disposal facilities,

and higher costs. On-site containment remedies include long-term protectiveness measures, such as caps and covers designed to remain effective for many years, routine inspections, maintenance, and groundwater monitoring.

The selection of source treatment, either by itself or in combination with non-treatment remedies for sources, has remained about the same as in previous years and is at 48 percent in the most recent three-year period (FYs 2021 to 2023).

Figure 5 shows trends for the selection of groundwater remedies in decision documents. In situ treatment had a consistently increasing trend through FY 2013 and has been fluctuating generally between 35 and 55 percent annually since FY 2014. P&T was generally steady in the 1980s with a range of approximately 60 to 80 percent (excluding 100 percent in FY 1982). From its peak at 85 percent in 1991, P&T has shown a generally decreasing trend to below 20 percent in 2010. Since then, P&T selection has typically ranged between 20 and 30 percent annually with an average of 23 percent. MNA generally increased until its peak of 46 percent in FY 1998. Since then, MNA has fluctuated from about 20 to 40 percent each FY. Approximately two thirds of recent groundwater decision documents continue to include ICs. Additionally, EPA determined that sites with recent groundwater decision documents that did not include ICs typically had selected ICs for the groundwater in a previous or subsequent decision document. Overall, 54 percent of decision documents with groundwater remedies select multiple remedial approaches, including various combinations of treatment, VEBs, MNA, and ICs.

Figure 5: Selection Trends for Decision Documents with Groundwater Remedies (FY 1981–2023)



- Number of groundwater decision documents = 2,783.
- Decision documents are included in more than one remedy category when they select multiple remedies.

Remedy data provided in Figures 4 and 5 show that a combination of remedies continues to be selected to address both source and groundwater, indicating the complexity of Superfund sites.

IV. Recent Remedy Selection (FY 2021–2023)

EPA conducted in-depth evaluation of the remedies selected in the 198 decision documents from FY 2021 to 2023 and presents an analysis for all source media and individual analyses for soil, sediment, and groundwater. In these remedy analyses, some decision documents have multiple remedies selected; therefore, numbers in each category are not additive to the totals. Although soil and sediment are included in the source analysis, they are also presented separately as they are the source media addressed most frequently. Appendix A lists the type and number of treatment technologies selected by fiscal year for source and groundwater, while Appendix B provides definitions of selected remedies.

Source Remedies

Of the 198 recent documents (FYs 2021 to 2023), 125 (63 percent) address source contamination at 106 sites. Table 3 provides further analysis of these 125 documents. The percentage of decision documents addressing sources is consistent with the previous period evaluated (FYs 2018 to 2020). Nearly 50 percent of recent source decision documents selected treatment, and 61 percent of documents selected containment/disposal remedies.

Table 3: Source Remedies Selected Most Frequently in Recent Decision Documents (FY 2021–2023)

Selected Remedy	Number	Percent
Treatment	**60**	**48%**
In Situ Treatment	34	27%
Thermal Treatment	14	11%
Soil Vapor Extraction	8	6%
Solidification/Stabilization	7	6%
Bioremediation	4	3%
Chemical Treatment	2	2%
Fracturing	2	2%
Other In Situ Treatment	6	5%
Ex Situ Treatment	31	25%
Physical Separation	17	14%
Solidification/Stabilization	7	6%
Open Burn/Open Detonation	3	2%
Recycling	2	2%
Other Ex Situ Treatment	5	4%
Containment/Disposal	**76**	**61%**
Disposal (off-site)	60	48%
Containment (on-site)	40	32%

Selected Remedy	Number	Percent
Monitored Natural Recovery/ Enhanced Monitored Natural Recovery	5	4%
Institutional Controls	83	66%
Other	38	30%

- Percentages based on 125 source decision documents issued in FYs 2021 through 2023.
- Other In Situ Treatment includes amended caps for sediments (1), amendments for sediments (1), constructed treatment wetland (1), and unspecified in situ treatment (3).
- Other Ex Situ Treatment includes thermal desorption (1) and unspecified ex situ treatment (4).
- Other remedies include fencing and signs (23), wetlands restoration (11), population relocation (4), revegetation (3), wetlands replacement (2), shoreline stabilization (1), stream realignment (1), and habitat restoration (1).

The selection of in situ treatment decreased from 34 percent in FYs 2018 to 2020 to 27 percent in the most recent three years. Thermal treatment was the in situ technology selected most frequently and has stayed steady near 10 percent from 2018 to 2023. The selection of ex situ treatment stayed relatively the same, at 27 percent in FYs 2018 to 2020 and 25 percent in FYs 2021 to 2023.

Physical separation processes include dewatering; sifting, sieving, and sorting solid media to separate components; and oil/water separation for NAPL. These processes are classified as treatment because they reduce the volume of contaminated material. Other remedies include fencing and signs, wetlands restoration, population relocation, revegetation, wetlands replacement, shoreline stabilization, stream realignment, and habitat restoration.

Soil Remedies

Of the 125 recent source decision documents (FYs 2021 to 2023), 94 (75 percent) address soil contamination at 82 sites. Table 4 summarizes the specific types of soil remedies selected in these decision documents. Thirty-eight documents (40 percent) selected treatment, and 52 documents (55 percent) selected containment/disposal.

Table 4: Soil Remedies Selected Most Frequently in Recent Decision Documents (FY 2021–2023)

Selected Remedy	Number	Percent
Treatment	**38**	**40%**
In Situ Treatment	26	28%
Thermal Treatment	12	13%
Soil Vapor Extraction	8	9%
Solidification/Stabilization	6	6%
Chemical Treatment	2	2%
Fracturing	2	2%
Other In Situ Treatment	2	2%
Ex Situ Treatment	15	16%
Physical Separation	6	6%
Solidification/Stabilization	6	6%
Other Ex Situ Treatment	4	4%
Containment/Disposal	**52**	**55%**
Disposal (off-site)	43	46%
Containment (on-site)	28	30%
Institutional Controls	**63**	**67%**
Other	**24**	**26%**

- Percentages based on 94 soil decision documents issued in FYs 2021 through 2023.
- Other In Situ Treatment includes unspecified in situ treatment (2).
- Other Ex Situ Treatment includes recycling (1) and unspecified ex situ treatment (3).
- Other remedies include fencing and signs (14), wetlands restoration (7), population relocation (3), and wetlands replacement (1).

The recent most frequently selected in situ technologies for soil are in situ thermal treatment (ISTT), soil vapor extraction (SVE), and solidification/stabilization (S/S).

S/S and physical separation are the most frequently selected remedies for the ex situ treatment of soil. Of the six recent decision documents that selected physical separation, five selected dewatering and one selected screening of soil.

On-site source containment was selected in 30 percent of soil documents and consists primarily of caps and cover systems. Nearly half of the documents addressing soil include off-site disposal. Although some waste sent for off-site disposal is treated prior to disposal in accordance with waste disposal regulations, it is not included as treatment in this analysis, if the treatment is not specified in the decision document.

Sediment Remedies

Of the 125 recent source decision documents (FYs 2021 to 2023), 29 (23 percent) address sediment contamination at 24 sites. Table 5 summarizes the specific types of sediment remedies selected in these decision documents. Most (79 percent) include disposal or containment of sediment, while 69 percent include treatment. Almost half (48 percent) include ICs, and more than half (55 percent) include other remedies, such as wetlands restoration, fencing, revegetation, wetlands replacement, shoreline stabilization, stream realignment, and habitat restoration. Physical separation was the most common treatment method selected (48 percent), which often includes dewatering of sediments. In situ treatment of sediments includes bioremediation and use of amendments, either as part of a cap or applied to the sediment directly. MNR was selected in four decision documents, and EMNR was selected once.

Table 5: Sediment Remedies Selected Most Frequently in Recent Decision Documents (FY 2021–2023)

Selected Remedy	Number	Percent
Treatment	**20**	**69%**
In Situ Treatment	3	10%
Amended Cap	1	3%
Amendments	1	3%
Bioremediation	1	3%
Ex Situ Treatment	19	66%
Physical Separation	14	48%
Solidification/Stabilization	4	14%
Other Ex Situ Treatment	1	3%
Containment/Disposal	**23**	**79%**
Disposal (off-site)	17	59%
Containment (on-site)	9	31%
Monitored Natural Recovery/ Enhanced Monitored Natural Recovery	**5**	**17%**
Institutional Controls	**14**	**48%**
Other	**16**	**55%**

- Percentages based on 29 sediment decision documents issued in FYs 2021 through 2023.
- Other Ex Situ Treatment includes unspecified ex situ treatment (1).
- Other remedies include wetlands restoration (9), fencing and signs (6), revegetation (3), wetlands replacement (1), shoreline stabilization (1), stream realignment (1), and habitat restoration (1).

Groundwater Remedies

Of the 198 recent documents (FYs 2021 to 2023), 112 (57 percent) address groundwater contamination at 105 sites. As shown in Table 6, 65 groundwater decision documents (58 percent) selected treatment remedies.

Table 6: Groundwater Remedies Selected Most Frequently in Recent Decision Documents (FY 2021–2023)

Selected Remedy	Number	Percent
Treatment	**65**	**58%**
In Situ Treatment	48	43%
Bioremediation	28	25%
Chemical Treatment	23	21%
Carbon Amendments	8	7%
Thermal Treatment	7	6%
Air Sparging	4	4%
Vapor Extraction	3	3%
Flushing	2	2%
Free Product Recovery	2	2%
Other In Situ Treatment	6	5%
Ex Situ Treatment (P&T)	22	20%
Vertical Engineered Barrier	**1**	**1%**
Monitored Natural Attenuation	**23**	**21%**
Institutional Controls	**75**	**67%**
Alternative Water Supply	**11**	**10%**
Other	**11**	**10%**

- Percentages based on 112 groundwater decision documents issued in FYs 2021 through 2023.
- Other In Situ Treatment includes constructed engineered wetland (1), fracturing (1), permeable reactive barrier (1), phytoremediation (1), solidification/stabilization (1), and unspecified in situ treatment (1).
- Other remedies include fencing and signs (9), phytoremediation (for hydraulic control) (2), and wetlands restoration (1).

In situ treatment was selected in 43 percent of the 112 groundwater decision documents with bioremediation (25 percent) and chemical treatment (21 percent) selected most frequently. For decision documents that selected bioremediation, 16 (57 percent) specified anaerobic bioremediation, 9 (32 percent) indicated bioaugmentation, and 8 (29 percent) specified aerobic bioremediation. When documents selected chemical treatment, 14 (61 percent) specified in situ chemical reduction (ISCR), up from 21 percent over the previous three years, while 13 (57 percent) selected in situ chemical oxidation (ISCO), down from nearly 85 percent over the same time period. Five documents selected both ISCO and ISCR with two selecting ISCO/ISCR together and three selecting ISCO or ISCR (to be determined during remedial design).

The use of in situ carbon amendments, also referred to as activated carbon (AC)-based technology, is included in the SRR for the first time in this edition, with eight selections over the past three years. This technology involves the injection of AC, typically along with other amendments, to adsorb groundwater contaminants and allow for additional remediation to occur. The use of AC

for groundwater treatment is not a new technology; however, applying it in situ is an innovative approach. Six of the eight decision documents selected carbon amendments in combination with another remedy: ISCR and bioremediation (3), bioremediation only (2), and ISCR only (1); two selections did not specify additional remedies. Additional information about this new approach is included in Appendix B.

After bioremediation and chemical treatment, P&T and MNA are the next most frequently selected remedies in recent groundwater decision documents at approximately 20 percent each.

V. Overview of Contaminants

EPA evaluated the types of COCs at Superfund sites based on decision documents at 1,570 sites. COC data were unavailable for 8 of the 1,578 sites with remedies. The COCs at a Superfund site may be in the same or different media and may be addressed by the same or different remedies.

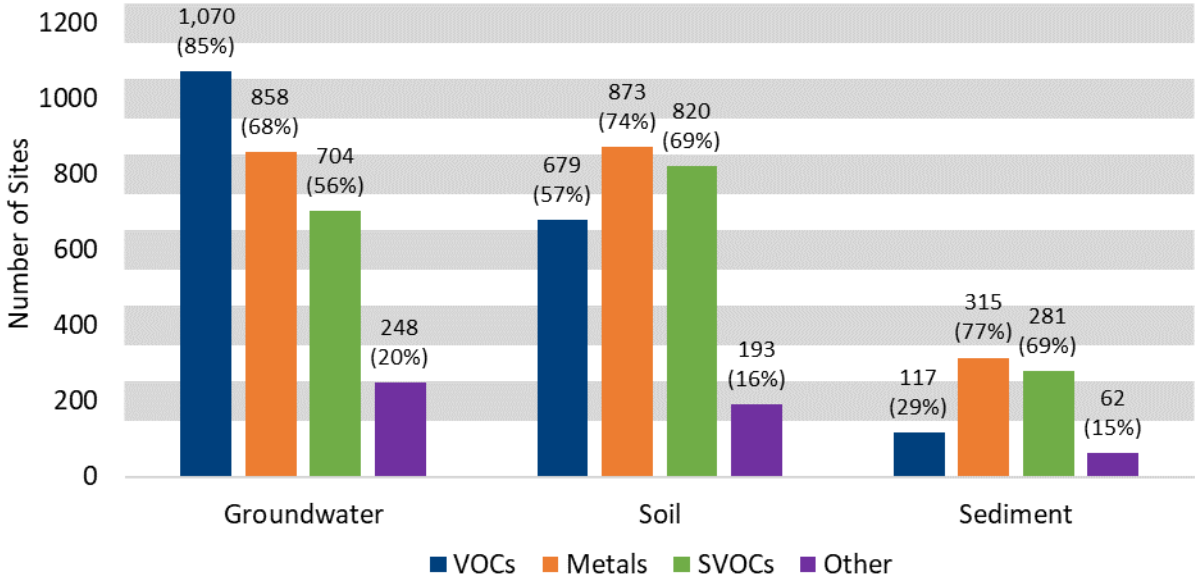
For this report, contaminants are categorized in three major groups based on general treatability: metals, volatile organic compounds (VOCs), and semivolatile organic compounds (SVOCs). Any contaminant that does not fit into one of those groups is categorized as "other." Appendix C lists individual contaminants and their associated contaminant groups.

The major contaminant groups are defined below:

- **Metals** – Metals; metalloids; explosive metals; radioactive metals; and organometallic pesticides and herbicides.
- **VOCs** – Halogenated VOCs (primarily chlorinated VOCs); benzene, toluene, ethylbenzene, xylene (BTEX); and other nonhalogenated VOCs.
- **SVOCs** – Polychlorinated biphenyls (PCBs); polycyclic aromatic hydrocarbons (PAHs); organic pesticides and herbicides; phenols; most fuels and distillates; most explosives; dioxins and furans; and other halogenated and nonhalogenated SVOCs.
- **Other** – nonmetallic inorganics; asbestos; and unspecified organics or inorganics.

EPA analyzed COCs by the three media most frequently targeted for remediation (groundwater, soil, and sediment) (Figure 6). On a site-wide basis, VOCs, metals, and SVOCs are all common in groundwater and soil, while metals and SVOCs are the most common COCs in sediment. Additional analysis concluded that nearly three-quarters have more than one contaminant group, while more than half have all three groups: VOCs, SVOCs, and metals.

Figure 6: Major Contaminant Groups by Media at Superfund Sites (FY 1981–2023)



- Number of groundwater sites with identified COCs = 1,256.
- Number of soil sites with identified COCs = 1,181.
- Number of sediment sites with identified COCs = 408.

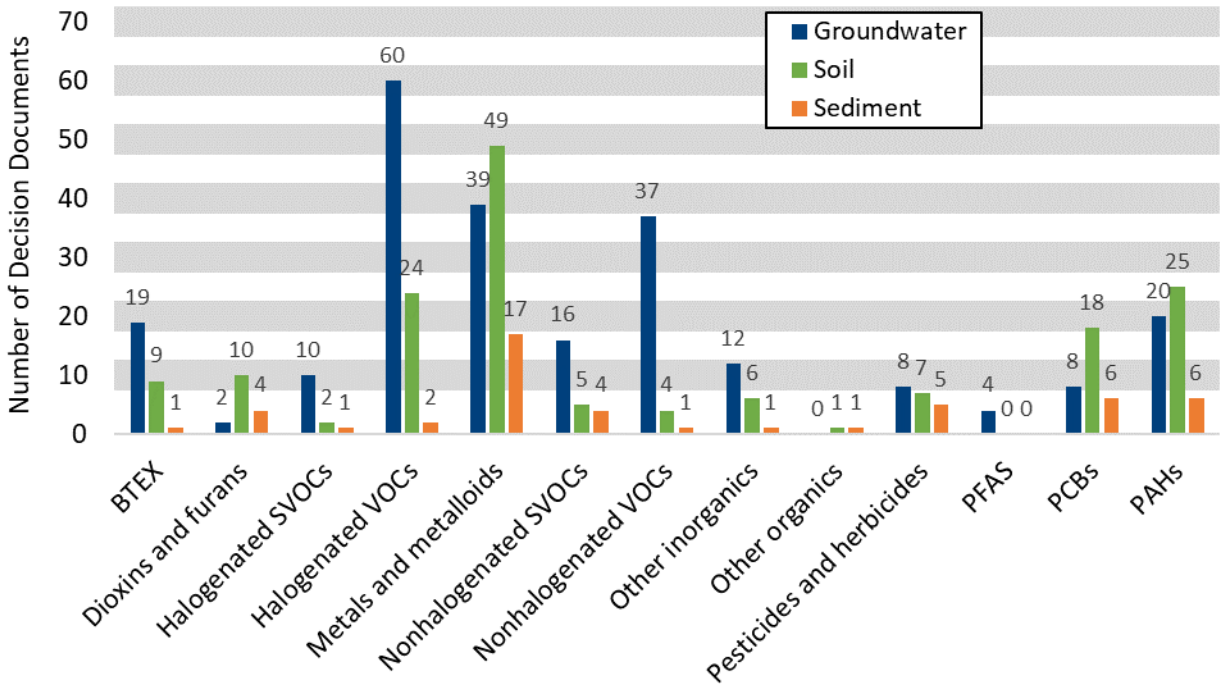
VI. Detailed Contaminant Groups Addressed in Recent Decision Documents (FY 2021–2023)

A further breakdown of contaminants shows which detailed contaminant groups are addressed most frequently in recent groundwater, soil, and sediment documents (Figure 7). Decision documents typically identify COCs addressed by selected remedies. ESDs are included in this contaminant analysis if they revise COCs, even if they do not change a remedial component. Some decision documents may not include COCs because (1) they are a ROD amendment or ESD that changes a remedial component but not a COC or (2) the media being addressed does not typically list COCs, such as a solid waste landfill.

EPA notes that per- and polyfluoroalkyl substances (PFAS), including perfluorooctanesulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), are included as their own category for the first time in Figure 7. EPA designated both PFOS and PFOA as hazardous substances under CERCLA in 2024.[5] As such, EPA anticipates that the number of decision documents addressing PFAS is likely to increase in the future.

[5] Designation of Perfluorooctanoic Acid (PFOA) and Perfluorooctanesulfonic Acid (PFOS) as CERCLA Hazardous Substances. 40 CFR Part 302. Federal Register. Volume 89, No. 90. May 8, 2024. https://www.govinfo.gov/content/pkg/FR-2024-05-08/pdf/2024-08547.pdf

Figure 7: Detailed Contaminant Groups Addressed in Recent Decision Documents (FY 2021–2023)



- Number of groundwater decision documents with identified COCs = 100.
- Number of soil decision documents with identified COCs = 77.
- Number of sediment decision documents with identified COCs = 26.

Halogenated VOCs, metals and metalloids, and nonhalogenated VOCs are the most common detailed contaminant groups included in recent groundwater decision documents. Metals and metalloids, PAHs, and halogenated VOCs are addressed most frequently in soil, while metals and metalloids, PAHs, and PCBs are most common for sediment.

Additional analysis showed many recent decision documents address multiple detailed contaminant groups. For example, 44 percent of recent groundwater decision documents with COCs have more than one contaminant group (44 of 100). Nearly half of recent documents with soil remedies address more than one contaminant group (36 of 77), and nearly 40 percent of recent sediment documents address multiple contaminant groups (10 of 26).

The detailed contaminant groups above were further broken down, and the individual contaminants identified most frequently are shown in Table 7 for groundwater, soil, and sediment. Over the last three years, trichloroethylene (TCE) remained the COC most frequently identified for groundwater, while lead remained the most common COC in both soil and sediment. In January 2024, EPA lowered the recommended screening level for lead in residential soil from 400 to 200 parts per million (ppm). As such, EPA anticipates this may increase the number of sites or volume of soil addressing lead contamination.

Table 7: Most Frequently Identified Contaminants of Concern in Recent Decision Documents (FY 2021–2023)

Contaminant of Concern	Number	Percent
Groundwater	(100 Decision Documents)	
Trichloroethene	46	46%
Chloroethene (vinyl chloride)	41	41%
Tetrachloroethene	30	30%
Cis-1,2-dichloroethene	29	29%
1,4-Dioxane	28	28%
Arsenic	24	24%
1,1-Dichloroethene	18	18%
Naphthalene	17	17%
Chloroform	17	17%
Lead	16	16%
Soil	(77 Decision Documents)	
Lead	33	43%
Trichloroethene	17	22%
Arsenic	16	21%
Benzo[a]pyrene	14	18%
Polychlorinated biphenyls (PCBs)	13	17%
Chromium	12	16%
Benzo(b)fluoranthene	11	14%
Benzo[a]anthracene	11	14%
Dibenzo(a,h)anthracene	11	14%
Zinc	11	14%
Sediment	(26 Decision Documents)	
Lead	10	38%
Chromium	6	23%
Mercury	6	23%
Polychlorinated biphenyls (PCBs)	6	23%
Copper	5	19%
Arsenic	4	15%
Bis(2-ethylhexyl)phthalate	4	15%
Cadmium	4	15%
Polycyclic aromatic hydrocarbons (PAHs)	4	15%
Zinc	4	15%

VII. Vapor Intrusion

Data for remedies that target air and soil gas media to address vapor intrusion have been tracked since 2009 starting with the *SRR 14th Edition* issued in November 2013. From FYs 2009 to 2023, a

total of 197 decision documents have addressed vapor intrusion at 151 sites. Forty-three of these documents have been issued in the last three years (FYs 2021 to 2023) and include a combination of vapor intrusion mitigation for existing structures (21), ICs for both existing structures (17) and future construction (31), and permanent relocation of a resident (1).

VIII. Conclusions

Most Superfund sites continue to use multiple remedial approaches to address multiple media and types of contaminants. Remedy selection through FY 2023 is consistent with CERCLA's preference for treatment as 84 percent of Superfund sites selected a treatment remedy for source media, groundwater, or both. Nearly three-quarters (74 percent) of the 1,578 sites with a remedy have selected remedies to address both source media and groundwater. On a site-wide basis, VOCs, SVOCs, and metals are all common in groundwater and soil at Superfund sites, while metals and SVOCs are the most common COCs in sediment. EPA recently designated PFOS and PFOA as hazardous substances and anticipates an increase in decision documents identifying these contaminants as COCs.

Table 8 presents a comparison of remedies selected in the previous two three-year periods (FYs 2015 to 2017 and FY 2018 to 2020) with the most recent three years (FYs 2021 to 2023). Data from FYs 2015 to 2017 and FYs 2018 to 2020 are presented in the *SRR 16th and 17th Editions*, respectively, while FYs 2021 to 2023 are shown in Tables 3 and 6 of this report. Historical data can be found in the trendlines provided in Figures 4 and 5. The percentage for each remedy category shown in Table 8 has decreased since the previous SRR. This is likely because of the recent increase in the percentage of ESDs per FY. Because ESDs typically include modifications for one type of remedial component as opposed to RODs, which typically include multiple remedy categories, the total number of remedy selections is down from FYs 2021 to 2023 when compared to FYs 2018 to 2020.

Table 8: Comparison of Remedy Selection Data (FY 2015–2017, FY 2018–2020, and FY 2021–2023)

Selected Remedy		FY 2015–2017	FY 2018–2020	FY 2021–2023
Source	Treatment	42%	50%	48%
	In Situ Treatment	20%	34%	27%
	Ex Situ Treatment	29%	27%	25%
	Containment/Disposal	67%	67%	61%
	Disposal (off-site)	45%	52%	48%
	Containment (on-site)	46%	39%	32%
	Institutional Controls	71%	69%	66%
Groundwater	Treatment	65%	67%	58%
	In Situ Treatment	51%	47%	43%
	Ex Situ Treatment (P&T)	20%	31%	20%
	MNA	20%	31%	21%
	Institutional Controls	71%	75%	66%

Most remedy types for both source and groundwater show no clear increasing or decreasing trend except for on-site containment, which is slightly downward, and off-site disposal of sources, which

is slightly upward. Remedy trends appear to be generally stable with each remedy type having its own range of fluctuations. ISTT and SVE remain the most common treatment technologies for soil, while physical separation (dewatering) remains the most common for sediments. In situ bioremediation, in situ chemical treatment, and P&T continue to be the most frequently selected treatment remedies for groundwater. The selection of carbon amendments for in situ groundwater treatment is increasing with eight selections in the last three years.

IX. Sources and Electronic Versions

This section lists the sources of information used in this report and its appendices and provides information on how to access the electronic version of this report and previous versions of the ASR and SRR.

Sources

EPA. 1991a. A Guide to Principal Threat and Low Level Threat Wastes. Office of Solid Waste and Emergency Response (OSWER). November. Publication 9380.3-06FS. https://semspub.epa.gov/src/document/05/382007.pdf

EPA. 1991b. Remediation of Contaminated Sediments. Office of Research and Development. April. EPA/625/6-91/028. https://semspub.epa.gov/src/document/HQ/189668.pdf

EPA. 1996. A Citizen's Guide to Soil Washing. OSWER. April. EPA 542-F-96-002. https://nepis.epa.gov/Exe/ZyPDF.cgi/10002SYY.PDF?Dockey=10002SYY.PDF

EPA. 1997a. Analysis of Selected Enhancements for Soil Vapor Extraction. OSWER. September. EPA 542-R-97-007. https://semspub.epa.gov/src/document/HQ/134629.pdf

EPA. 1997b. Presumptive Remedy: Supplemental Bulletin Multi-Phase Extraction (MPE) Technology for VOCs in Soil and Groundwater. OSWER. April. EPA 540-F-97-004. https://semspub.epa.gov/src/document/HQ/174624.pdf

EPA. 1998. Field Applications of In Situ Remediation Technologies: Ground-Water Circulation Wells. OSWER. October. EPA 542-R-98-009. https://semspub.epa.gov/src/document/HQ/134593.pdf

EPA. 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. OSWER. April 21. OSWER Directive No. 9200.4-17P. https://nepis.epa.gov/Exe/ZyPDF.cgi/2000ISUG.PDF?Dockey=2000ISUG.PDF

EPA. 2000. Engineered Approaches to In Situ Bioremediation of Chlorinated Solvents. OSWER. July. EPA 542-R-00-008. https://semspub.epa.gov/src/document/HQ/134557.pdf

EPA. 2001. Use of Bioremediation at Superfund Sites. OSWER. September. EPA 542-R-01-019. https://www.epa.gov/sites/production/files/2015-08/documents/bioremediation_542r01019.pdf

EPA. 2005. Contaminated Sediment Remediation Guidance for Hazardous Waste Sites. OSWER. December. EPA 540-R-05-012. https://semspub.epa.gov/src/document/HQ/174471.pdf

EPA. 2006. In Situ Treatment Technologies for Contaminated Soil: Engineering Forum Issue Paper. OSWER. November. EPA 542-F-06-013. https://www.epa.gov/sites/production/files/2015-04/documents/tsp_issue_paper_542f06013.pdf

EPA. 2007. The Use of Soil Amendments for Remediation, Revitalization, and Reuse. OSWER. December. EPA 542-R-07-013. https://semspub.epa.gov/src/document/11/176023.pdf

EPA. 2008a. Engineering Issue: Indoor Air Vapor Intrusion Mitigation Approaches. National Risk Management Research Laboratory; Office of Research and Development. October. EPA 600-R-08-115. https://www.epa.gov/sites/production/files/2015-09/documents/600r08115.pdf

EPA. 2008b. Understanding the Superfund Alternative Approach. OSWER. April. EPA 330-R-08-001. https://semspub.epa.gov/src/document/HQ/189821.pdf

EPA. 2008c. Wetlands Compensatory Mitigation. Office of Wetlands, Oceans and Watersheds. EPA 843-F-08-002. https://www.epa.gov/sites/production/files/2015-08/documents/compensatory_mitigation_factsheet.pdf

EPA. 2010. Update on Providing Alternative Water Supply as Part of Superfund Response Actions. OSWER. September. OSWER Directive No. 9355.3-22. https://semspub.epa.gov/src/document/HQ/175200.pdf

EPA. 2011. Fact Sheet on Evapotranspiration Cover Systems for Waste Containment. OSWER. February. EPA 542-F-11-001. https://semspub.epa.gov/src/document/HQ/153848.pdf

EPA. 2013a. In Situ Amendments. Office of Land and Emergency Management (OLEM). April. Infographic. https://semspub.epa.gov/src/document/HQ/100000673

EPA. 2013b. Use of Amendments for In Situ Remediation at Superfund Sediment Sites. OSWER April. OSWER Directive 9200.2-128FS. https://semspub.epa.gov/src/document/HQ/196704.pdf

EPA. 2015. OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air. OSWER. June. Publication 9200.2-154. https://semspub.epa.gov/src/document/HQ/190145.pdf

EPA. 2021a. Community Guide to Granular Activated Carbon Treatment. OLEM. EPA 542-F-21-010. https://semspub.epa.gov/src/document/HQ/401595

EPA. 2021b. Community Guide to Air Stripping. OLEM. EPA 542-F-21-001. https://semspub.epa.gov/src/document/HQ/401577

EPA. 2021c. Community Guide to Capping. OLEM. EPA 542-F-21-005. https://semspub.epa.gov/src/document/HQ/401585

EPA. 2021d. Community Guide to Fracturing for Site Cleanup. OLEM. EPA 542-F-21-009. https://semspub.epa.gov/src/document/HQ/401593

EPA. 2021e. Community Guide to In Situ Chemical Reduction. OLEM. EPA 542-F-21-014. https://semspub.epa.gov/src/document/HQ/401603

EPA. 2021f. Community Guide to In Situ Thermal Treatment. OLEM. EPA 542-F-21-016. https://semspub.epa.gov/src/document/HQ/401607

EPA. 2021g. Community Guide to Incineration. OLEM. EPA 542-F-21-017. https://semspub.epa.gov/src/document/HQ/401609

EPA. 2021h. Community Guide to Pump and Treat. OLEM. EPA 542-F-21-021. https://semspub.epa.gov/src/document/HQ/401617

EPA. 2021i. Community Guide to Soil Vapor Extraction and Air Sparging. OLEM. EPA 542-F-21-022. https://semspub.epa.gov/src/document/HQ/401619

EPA. 2021j. Community Guide to Solidification and Stabilization. OLEM. EPA 542-F-21-023. https://semspub.epa.gov/src/document/HQ/401621

EPA. 2021k. Community Guide to Thermal Desorption. OLEM. EPA 542-F-21-024. https://semspub.epa.gov/src/document/HQ/401623

EPA. 2021l. Community Guide to Vapor Intrusion Mitigation. OLEM. EPA 542-F-21-025. https://semspub.epa.gov/src/document/HQ/401625

EPA. 2021m. Community Guide to Vertical Engineered Barriers. OLEM.EPA 542-F-21-026. https://semspub.epa.gov/src/document/HQ/401627

EPA. 2022a. Activated Carbon-Based Technology for In Situ Remediation. https://cluin.org/techfocus/default.focus/sec/Activated_Carbon-Based_Technology_for_In_Situ_Remediation/cat/Overview/. August

EPA. 2022b. Dense Nonaqueous Phase Liquids (DNAPLs). https://cluin.org/contaminantfocus/default.focus/sec/Dense_Nonaqueous_Phase_Liquids_(DNAPLs)/cat/Treatment_Technologies/p/3. September 8.

EPA. 2022c. Thermal Treatment: In Situ. https://cluin.org/techfocus/default.focus/sec/Thermal_Treatment%3A_In_Situ/cat/Overview/. December 15.

Environmental Security Technology Certification Program (ESTCP). 2012. Combining Low-Energy Electrical Resistance Heating with Biotic and Abiotic Reactions for Treatment of Chlorinated Solvent DNAPL Source Areas. ESTCP Project ER-200719. December.

Federal Remediation Technologies Roundtable (FRTR). 2022. Technology Screening Matrix. https://frtr.gov/matrix/default.cfm. Accessed on September 29.

Interstate Technology & Regulatory Council (ITRC). 1997. Technical and Regulatory Guidelines for Soil Washing. Metals in Soil Workgroup. Washington, D.C. December. MIS-1. https://www.environmentalrestoration.wiki/images/3/3c/ITRC-1997-Tech_%26_Reg_Guidelines_for_Soil_Washing.pdf

ITRC. 2003. Technical and Regulatory Guidance Document for Constructed Treatment Wetlands. Wetlands Work Group. Washington, D.C. December. WTLND-1. https://frtr.gov/pdf/wtland-1.pdf

ITRC. 2007. Technical and Regulatory Guidance Document for Vapor Intrusion Pathway: A Practical Guideline. Washington, D.C. January. VI-1. https://itrcweb.org/wp-content/uploads/2024/09/VI-1.pdf

ITRC. 2011. Permeable Reactive Barrier: Technology Update. Permeable Reactive Barrier Work Group. Washington, D.C. June. PRB-5-1. https://semspub.epa.gov/src/document/09/1142231.pdf

Karn, Barbara; Kuiken, Todd; and Otto, Martha. 2009. Nanotechnology and in Situ Remediation: A Review of the Benefits and Potential Risks. Environmental Health Perspectives. December. Volume 117, Number 12. pp. 1823–1831. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2799454

Nielsen, K.B. and B. Hvidberg. 2017. Remediation Techniques for Mitigating Vapor Intrusion from Sewer Systems to Indoor Air. Remediation. Volume 27, Issue 3. Pages 67–73. https://doi.org/10.1002/rem.21520

Electronic Versions

SRR 18th Edition is available electronically at https://www.epa.gov/remedytech/superfund-remedy-report.

Appendix A: Treatment Technologies by Fiscal Year lists the ex situ and in situ source treatment technologies, groundwater in situ treatment technologies, and groundwater P&T remedies by FY from 1981 to 2023.

Appendix B: Definitions of Selected Remedies defines the specific remedies selected as part of remedial actions.

Appendix C: Individual Contaminants and Assigned Contaminant Groups lists the individual contaminants from decision documents and identifies to which contaminant groups the individual contaminants were assigned.

The data that form the basis of the analyses contained in the *SRR 18th Edition* can be found at https://www.epa.gov/superfund/superfund-data-and-reports by downloading *Contaminant of Concern Data for Decision Documents by Media, FY 1981–2023* and *Remedy Component Data for Decision Documents by Media, FY 1981–2023*.

In addition, previous editions of the ASR and SRR can be downloaded from https://www.epa.gov/remedytech/superfund-remedy-report

APPENDIX A

TREATMENT TECHNOLOGIES BY FISCAL YEAR

Appendix A: Treatment Technologies by Fiscal Year

Type	Remedy	81–85	86–90	91–95	96–00	01–05	06–10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
Ex Situ Source Treatment	Acid Extraction	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	Aeration	1	10	4	6	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	24
	Bioremediation	1	24	34	23	9	5	1	0	0	1	0	1	0	1	0	0	0	0	0	100
	Chemical Treatment	1	6	13	7	6	2	1	0	1	1	1	0	0	0	0	0	0	0	0	40
	Constructed Treatment Wetland	0	0	1	0	0	2	1	0	0	1	1	0	0	0	0	0	0	0	0	6
	Incineration	2	9	8	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24
	Incineration (off-site)	13	39	55	24	6	3	0	5	0	0	0	2	0	1	0	0	0	0	0	148
	Incineration (on-site)	4	55	21	5	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	87
	Neutralization	1	1	5	3	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	13
	Open Burn/Open Detonation	0	0	2	1	2	1	0	0	0	0	0	0	1	1	0	1	0	1	2	12
	Physical Separation	15	75	101	67	47	40	10	11	6	12	6	8	8	9	6	9	6	2	9	447
	Phytoremediation	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
	Recycling	1	24	42	24	19	13	3	3	5	5	2	2	1	3	1	1	1	1	0	151
	Soil Vapor Extraction	1	6	12	6	4	1	0	0	1	0	0	1	1	0	0	0	0	0	0	33
	Soil Washing	0	16	11	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33
	Solidification/Stabilization	2	66	99	49	34	44	5	3	1	2	1	0	2	5	1	6	3	2	2	327
	Source P&T	12	40	44	15	12	6	1	2	1	0	3	4	0	2	0	2	0	0	0	144
	Thermal Desorption	0	7	22	22	7	1	0	0	1	0	1	0	0	0	0	0	0	1	0	62
	Thermal Treatment	0	24	15	12	2	2	0	2	0	0	1	0	3	0	0	2	0	0	0	63
	Unspecified Ex Situ Treatment	0	0	3	1	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	7
	Unspecified Ex Situ Treatment (off-site)	4	16	17	17	16	13	6	2	1	5	1	1	7	3	1	1	2	1	0	114
	Unspecified Ex Situ Treatment (on-site)	2	11	12	7	6	1	0	4	0	2	0	0	1	1	0	0	0	0	0	47
In Situ Source Treatment	Amended Cap (for sediment)	0	0	0	0	0	2	0	0	2	1	1	0	1	2	0	2	0	1	0	12
	Amendments (for sediment)	0	0	0	0	0	0	0	0	0	0	1	0	1	2	0	0	0	1	0	5
	Bioremediation	0	9	28	39	11	13	2	1	2	4	4	1	1	4	2	3	0	3	1	128
	Chemical Treatment	0	1	1	3	3	16	4	3	3	7	3	1	2	2	4	4	1	1	0	58
	Constructed Treatment Wetland	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	1	0	5
	Electrokinetics	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
	Flushing	1	15	14	6	1	3	0	0	0	0	1	0	0	2	0	0	0	0	0	43
	Fracturing	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	2	1	0	1	7
	Multi-phase Extraction	0	0	0	1	0	1	0	0	1	0	0	2	0	0	1	1	0	0	0	7
	Phytoremediation	0	0	0	4	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	7
	Soil Amendments	0	1	0	1	2	4	1	0	1	1	1	0	0	0	1	1	0	0	0	14
	Soil Vapor Extraction	0	43	85	69	46	34	9	2	6	6	2	2	4	7	2	4	5	2	1	329
	Solidification/Stabilization	4	19	36	50	20	20	3	2	3	2	2	3	4	5	5	3	4	3	0	188
	Thermal Treatment	0	15	29	20	6	14	0	5	3	3	2	3	3	9	3	6	7	4	3	135
	Unspecified In Situ Treatment	1	6	7	2	7	2	1	0	0	0	2	0	0	0	0	1	1	0	2	32

Type	Remedy	81–85	86–90	91–95	96–00	01–05	06–10	11	12	13	14	15	16	17	18	19	20	21	22	23	Total
Source Treatment (unspecified)	Unspecified Source Treatment	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	Unspecified Treatment (on-site)	8	21	23	16	13	5	1	0	0	0	0	0	0	0	0	0	0	0	0	87
In Situ Groundwater Treatment	Air Sparging	0	0	15	43	20	13	1	1	2	2	0	0	3	1	2	2	2	1	1	109
	Bioremediation	1	14	26	19	34	93	10	13	17	17	11	10	10	10	8	13	6	10	12	333
	Carbon Amendments	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	3	8
	Chemical Treatment	0	4	7	5	9	44	9	15	9	15	13	8	7	4	8	7	8	10	5	186
	Electrokinetics	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	3
	Flushing	0	1	0	0	1	0	0	0	1	0	1	0	0	1	0	0	1	0	1	7
	Fracturing	0	0	2	0	0	0	0	1	1	1	0	0	0	0	0	1	0	0	1	7
	Free Product Recovery	0	0	1	4	0	0	1	1	0	3	1	0	0	0	1	0	0	1	1	14
	In-well Air Stripping	0	0	0	2	3	2	0	0	1	1	0	0	0	0	1	0	0	0	0	10
	Multi-phase Extraction	0	1	1	4	4	5	1	0	2	0	1	1	2	1	1	1	0	0	0	25
	Permeable Reactive Barrier	0	0	4	7	14	10	4	0	4	3	0	4	1	1	2	0	0	1	0	55
	Phytoremediation	0	0	0	4	5	2	0	0	0	2	0	1	0	0	0	0	0	0	1	15
	Solidification/Stabilization	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	0	0	1	0	5
	Thermal Treatment	0	2	0	0	1	0	0	1	2	1	2	1	3	5	2	4	3	3	1	31
	Unspecified In Situ Treatment	1	3	7	9	17	5	0	0	1	2	1	1	1	0	1	1	0	1	0	51
	Vapor Extraction	0	0	9	21	1	6	1	0	0	0	0	0	1	0	2	0	1	0	2	44
	Constructed Treatment Wetland	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	0	0	3
Ex Situ Groundwater Treatment	Groundwater P&T	51	316	401	226	131	105	14	15	13	9	9	7	6	17	9	10	13	3	6	1,362
	Constructed Treatment Wetland	0	1	2	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	6

Data in Appendix A may vary from data presented in the *SRR 17th Edition*. EPA has updated the dataset to add remedy components for decision documents from the early years of the program that had not previously been recorded and has updated older data to conform more readily to recently updated media and remedy categories.

Appendix B

Definitions of Selected Remedies

Appendix B: Definitions of Selected Remedies

B.1 Treatment Technologies

Most treatment technologies were grouped into one of the four main treatment categories: biological, chemical, physical, or thermal treatment. Ex situ treatment technologies associated with pump and treat (P&T) systems are included separately as their own treatment category.

B.1.1 Biological Treatment

Biological treatment involves adding or stimulating the growth of microorganisms, which metabolize contaminants or create conditions under which contaminants chemically convert to non-hazardous or less toxic compounds or compounds that are more stable, less mobile, and/or inert. **Phytoremediation,** the use of plants to remove, stabilize, or destroy contaminants, is included in the definition of biological treatment.

Bioaugmentation is "[the] addition of microbes to the subsurface where organisms able to degrade specific contaminants are deficient. Microbes may be 'seeded' from populations already present at a site and grown in aboveground reactors or from specially cultivated strains of bacteria having known capabilities to degrade specific contaminants" (EPA, 2000).

Bioremediation "is a technology that uses microorganisms to treat contaminants through natural biodegradation mechanisms (intrinsic bioremediation) or by enhancing natural biodegradation mechanisms through the addition of microbes, nutrients, electron donors, and/or electron acceptors (enhanced bioremediation). This technology, performed *in situ* (below ground or in place) or *ex situ* (above ground), is capable of degrading organic compounds to less toxic materials such as carbon dioxide, methane, and water through aerobic or anaerobic processes" (EPA, 2001).

Constructed Treatment Wetlands are "manmade wetlands built to remove various types of pollutants that may be present in water that flows through them. They are constructed to recreate, to the extent possible, the structure and function of natural wetlands…They possess a rich microbial community in the sediment to effect the biochemical transformation of pollutants, they are biologically productive, and…they are self-sustaining….[Constructed wetlands] utilize many of the mechanisms of phytoremediation" (ITRC, 2003). Note that the term "constructed wetlands" is used to refer only to wetlands constructed for the purposes of treatment and not to wetlands constructed to compensate for wetlands destroyed by a remedy (such as placement of a cap in a marsh). Such "compensatory wetlands" are considered "Wetlands Replacement."

Phytoremediation "uses [macroscopic] plants to extract, degrade, contain, or immobilize contaminants in soil, groundwater, and other contaminated media. The phytoremediation mechanisms used to treat contaminated [media]…are phytoextraction, rhizodegradation, phytodegradation, phytovolatilization, and phytostabilization" (EPA, 2006). Phytoremediation may be applied in situ or ex situ.

Note that while phytoremediation may include the use of microorganisms in conjunction with plants, it is distinguished from bioremediation in that bioremediation does not use macroscopic plants or trees. For purposes of this report, the use of plants to control surface water drainage, to influence groundwater movement, or to adjust the water table are not considered

phytoremediation since the purpose is not to extract the contaminants from the media. Such remedies are classified as engineering controls.

B.1.2 Chemical Treatment

Chemical treatment chemically converts hazardous contaminants to non-hazardous or less toxic compounds or compounds that are more stable, less mobile, inert, or all three. Even though a chemical reaction is not always involved in chemical precipitation, chemical precipitation is typically included in this category.

Amended Cap for sediment refers to a subaqueous cover in which "[specialized] materials [are] used to enhance the chemical isolation capacity…compared to sand caps. Examples include…reactive/adsorptive materials such as activated carbon, apatite, coke, organoclay, zero-valent iron and zeolite. Composite geotextile mats containing one or more of these materials (i.e., reactive core mats) are becoming available commercially" (EPA, 2005). These caps can also be applied to address sludge or solid waste contamination (for example, the bottom of a mining waste pit).

Amendments for sediments are "specialized materials used to reduce risk through in situ sequestering or destruction of contaminants in sediment" (EPA, 2013a). Examples include activated carbon, organoclay, and phosphate additives. "Direct amendment of surficial sediment with sorbents can reduce pollutant bioavailability to the food chain and flux of pollutants into the water column. Amendments can be spread on the surface of the contaminated sediment as a thin layer, intended to be mixed with the sediments through natural processes, or mixed into the surface using equipment similar to a rototiller" (EPA, 2013b). For amendments applied to soil, refer to Soil Amendments.

Chemical Fixation or Chemical Stabilization — See Solidification and Stabilization.

Chemical Oxidation "typically involves reduction/oxidation (redox) reactions that chemically convert hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, or inert. Redox reactions involve the transfer of electrons from one chemical to another. Specifically, one reactant is oxidized (loses electrons) and one is reduced (gains electrons). There are several oxidants capable of degrading contaminants. Commonly used oxidants include potassium or sodium permanganate, Fenton's catalyzed hydrogen peroxide, hydrogen peroxide, ozone, and sodium persulfate. Each oxidant has advantages and limitations, and while applicable to soil contamination and some source zone contamination, they have been applied primarily toward remediating groundwater" (EPA, 2006). Chemical oxidation can be conducted either in situ or ex situ.

Chemical Reduction "uses chemicals called 'reducing agents' to help change contaminants into less toxic or less mobile forms…In situ chemical reduction [ISCR] can clean up several types of contaminants dissolved in groundwater. ISCR is most often used to clean up the metal chromium and the industrial solvent trichloroethene.

"Common reducing agents include zero valent metals, which are metals in their pure form. The most common metal used in ISCR is zero valent iron, or 'ZVI.' ZVI must be ground up into small granules for use in ISCR. In some cases, micro- or nano-scale (extremely small) particles are used. The smaller particle size increases the surface area of iron available to react with contaminants.

Other common reducing agents include polysulfides, sodium dithionite and ferrous iron" (EPA, 2021e). ISCR agents are often injected into the subsurface or included in a permeable reactive barrier (PRB); however, when agents are part of a PRB, the remedy is considered a PRB and not ISCR.

In Situ Chemical Oxidation (ISCO) — See Chemical Oxidation.

In Situ Chemical Reduction (ISCR) — See Chemical Reduction.

Nanoremediation "methods entail the application of reactive nanomaterials for transformation and detoxification of pollutants. These nanomaterials have properties that enable both chemical reduction and catalysis to mitigate the pollutants of concern....Because of their minute size and innovative surface coatings, nanoparticles may be able to pervade very small spaces in the subsurface and remain suspended in groundwater, allowing the particles to travel farther than larger, macro-sized particles and achieve wider distribution....

"Many different nanoscale materials have been explored for remediation...Of these, nanoscale zero-valent iron (nZVI) is currently the most widely used....nZVI particles range from 10 to 100 [nanometers (nm)] in diameter....The high reactivity of nZVI particles is in part a direct result of their high specific surface area....nZVI's small particle size also allows more of the material to penetrate into soil pores, and it can be more easily injected into shallow and deep aquifers, a property that is particularly beneficial when contamination lies underneath a building" (Karn, Kuiken, & Otto, 2009).

Neutralization is a chemical reaction between an acid and a base. The reaction involves acidic or caustic wastes that are neutralized (pH is adjusted toward 7.0) using caustic or acidic additives.

Permeable Reactive Barriers (PRBs) are "in situ, permeable treatment zone[s] designed to intercept and remediate a contaminant plume. The term 'barrier' is intended to convey the idea that contaminant migration is impeded; however, the [permeable reactive barrier] is designed to be more permeable than the surrounding aquifer media so that groundwater can easily flow through the structure without significantly altering groundwater hydrology. The treatment zone may be created directly using reactive materials such as ZVI, or indirectly using materials designed to stimulate secondary processes (e.g., adding carbon substrate and nutrients to enhance microbial activity). In this way, contaminant treatment may occur through physical, chemical, or biological processes" (ITRC, 2011).

B.1.3 Physical Treatment

Physical treatment uses the physical properties of the contaminants or the contaminated medium to separate or immobilize the contamination.

Air Sparging "involves drilling one or more injection wells into the groundwater-soaked soil below the water table. An air compressor at the surface pumps air underground through the wells. As air bubbles flow through the groundwater, it carries contaminant vapors upward into the soil above the water table. The mixture of air and vapors is then pulled out of the ground for treatment using [soil vapor extraction (SVE)]" (EPA, 2021i). Oxygen added to the contaminated groundwater and vadose-zone soils also can enhance biodegradation of contaminants below and above the water table. The injection of ozone into the aquifer is referred to as ozone sparging and is a form of chemical treatment.

Carbon Amendments, also referred to as activated carbon (AC)-based technology, "involves emplacement of AC-based amendments for in situ remediation of soil and groundwater" (EPA, 2022a). These amendments typically include other reactive amendments commonly used with in situ remediation technologies, such as ISCR, ISCO, and bioremediation. "AC-based amendments remove contaminant via two processes: adsorption by AC and degradation by reactive amendments. Adsorption results in rapid initial removal of contaminants from the aqueous phase, whereas degradation subsequently destroys contaminants. The synergy between adsorption and degradation, either biotic or abiotic, has been investigated in numerous bench-scale studies" (EPA, 2022a). For purposes of the SRR, AC-based remedies are categorized separately from other reactive amendments to allow for the accurate capture of all processes being selected to address contamination.

Electrokinetics "is the process of applying an electrical current to the subsurface to create movement of ions with the objective of facilitating the removal of contaminants through a variety of processes. Early applications focused on the direct removal of heavy metals, radionuclides, and polar or ionizable organic contaminants from soils, sludges, and sediments. More recently, electrokinetics has been applied to facilitate distribution of various amendments required for in situ remediation technologies such as in situ chemical oxidation (ISCO) and enhanced reductive dechlorination [...]. Regardless of the treatment objectives and application methods, all in situ electrokinetic applications require the installation of several inert electrodes in the aquifer. Application of a low-voltage direct current [...] is applied to create the voltage gradient and electrical field to more evenly distribute amendments and remove contaminants from the aquifer" (FRTR, 2022).

Flushing "involves flooding a zone of contamination with an appropriate solution to remove the contaminant from the soil. Water or liquid solution is injected or infiltrated into the area of contamination. The contaminants are mobilized by solubilization, formation of emulsions, or a chemical reaction with the flushing solutions. After passing through the contamination zone, the contaminant-bearing fluid is collected and brought to the surface for disposal, recirculation, or on-site treatment and reinjection....Flushing solutions may be water, acidic aqueous solutions, basic solutions, chelating or complexing agents, reducing agents, cosolvents, or surfactants" (EPA, 2006).

Free Product Recovery removes either LNAPL or DNAPL contamination from the subsurface. LNAPL recovery "consists of several technologies ranging from simple hand bailers and passive skimmer systems to more complex active skimming systems and large-scale total fluids recovery systems. The objective of these recovery techniques is to remove LNAPL to the extent practicable, prevent its migration and reduce its impact to dissolved phase contaminants in groundwater" (FRTR, 2022). "Flowable masses of DNAPL are generally addressed by placing an interception trench in front of them if they are still moving or by placing an extraction well into the mass. The flowable material enters the trench where it moves to a sump and is recovered by bailing or pumping. In the case of a well, the removal of the DNAPL in the well creates an induced gradient in the DNAPL that causes the flowable mass around the well to move into it. Pumping or bailing are used to remove the DNAPL depending upon how much DNAPL is present and how fast it will flow into the well" (EPA, 2022b).

In Situ Geochemical Stabilization — See Solidification and Stabilization.

In-Well Air Stripping systems "create a circulation pattern in the aquifer by drawing water into and pumping it through the wells, and then reintroducing the water into the aquifer without bringing it above ground....The well is double-cased with hydraulically separated upper and lower screened intervals within the aquifer....The system can be configured with an upward in-well flow or a downward in-well flow. The most common configurations involve the injection of air into the inner casing, decreasing the density of the groundwater and allowing it to rise....Through this system, volatile contaminants in the ground water are transferred from the dissolved phase to the vapor phase by the rising air bubbles. Contaminated vapors can be drawn off and treated above ground or discharged into the vadose zone" (EPA, 1998).

Mechanical Soil Aeration agitates contaminated soil, using tilling or other means to volatilize contaminants.

Multi-Phase Extraction (MPE) "is an enhancement of the traditional SVE system. Unlike SVE, MPE simultaneously extracts both groundwater and soil vapor. The groundwater table is lowered in order to dewater the saturated zone so that the SVE process can be applied to the newly exposed soil. This allows the volatile compounds sorbed on the previously saturated soil to be stripped by the induced vapor flow and extracted. In addition, soluble VOCs present in the extracted groundwater are also removed" (EPA, 1997b). "[MPE] systems can be implemented to target all phases of contamination associated with a typical NAPL spill site. These systems remove residual vadose zone soil contamination residing in soil gas, dissolved in soil pore-space moisture, and adsorbed to soil particles. [MPE] also effectively removes dissolved and free-phase (both light and dense NAPL [LNAPL and DNAPL]) contamination in groundwater" (EPA, 1997a). Dual-phase extraction and bioslurping are types of MPE.

Physical Separation processes use physical properties to separate contaminated and uncontaminated media or to separate different types of media. For example, different-sized sieves and screens can be used to separate contaminated soil from relatively uncontaminated debris. Another application of physical separation is the dewatering of sediments or sludge. Physical separation is included as treatment because it reduces the volume of contaminated material.

Recycling is the process of collecting and processing materials that would otherwise require disposal and turning them into new products. Examples include recycling recovered oil and solvents.

Soil Vapor Extraction (SVE) "extracts vapors from the soil above the water table by applying a vacuum to pull the vapors out...SVE involves drilling one or more extraction wells into the contaminated soil to a depth above the water table, which must be deeper than 3 feet below the ground surface. Attached to the wells is equipment (such as a blower or vacuum pump) that creates a vacuum. The vacuum pulls air and vapors through the soil and up the well to the ground surface for treatment" (EPA, 2021i). SVE usually is performed in situ; however, in some cases, it can be used as an ex situ technology.

Soil Washing "is a process that uses physical and/or chemical techniques to separate contaminants from soil and sediments. Contaminants are concentrated into a much smaller volume of contaminated residue, which is either recycled or disposed. Washwater can consist of water only or can include additives such as acids, bases, surfactants, solvents, chelating or sequestering agents which are utilized to enhance the separation of contaminants from soils or sediments" (ITRC,

1997). "Hazardous contaminants tend to bind, chemically or physically, to silt and clay. Silt and clay, in turn, bind to sand and gravel particles. The soil washing process separates the contaminated fine soil (silt and clay) from the coarse soil (sand and gravel). When completed, the smaller volume of soil, which contains the majority of the fine silt and clay particles, can be further treated by other methods (such as incineration or bioremediation) or disposed of according to state and federal regulations" (EPA, 1996).

Solidification and Stabilization (S/S) "refer[s] to a group of cleanup methods that prevent or slow the release of harmful chemicals from wastes, such as contaminated soil, sediment, and sludge. These methods usually do not destroy the contaminants. Instead, they keep them from 'leaching' above safe levels into the surrounding environment…Solidification and stabilization are often used together to prevent people and wildlife from being exposed to metals, radioactive contaminants, and some types of organic contaminants, such as PCBs and pesticides….

"Solidification involves mixing a waste with a binding agent, which is a substance that makes loose materials stick together. Common binding agents include cement, asphalt, fly ash, and clay. Water must be added to most mixtures for binding to occur; then the mixture dries and hardens to form a solid block.

"Like solidification, stabilization also involves mixing wastes with binding agents. However, the binding agents cause a chemical reaction with contaminants to make them less likely to be released into the environment. For example, when soil contaminated with metals is mixed with water and lime — a white powder produced from limestone — a reaction changes the metals into a form that will not dissolve in water" (EPA, 2021j). Stabilization remedies are classified as S/S whether or not they ultimately involve solidification.

S/S may be performed either ex situ or in situ.

Solvent Extraction uses an organic solvent as an extractant to separate contaminants from soil. The organic solvent is mixed with contaminated soil in an extraction unit. The extracted solution is then passed through a separator, where the contaminants and extractant are separated from the soil.

B.1.4 Thermal Treatment

Thermal treatment uses heat to separate contaminants from contaminated media by increasing their mobility. Thermal treatment includes volatility; destroying contaminants or contaminated media by burning, decomposing, or detonating the contaminants or the contaminated media; or immobilizing contaminants by melting and solidifying the contaminated media.

Electrical Resistance Heating "uses arrays of electrodes installed around a central neutral electrode to create a concentrated flow of current toward the central point. Resistance to flow in the soils generates heat greater than 100°C, producing steam and readily mobile contaminants that are recovered via vacuum extraction and processed at the surface" (EPA, 2022c). A low-energy electrical resistance heating approach raises the subsurface temperatures to approximately 30 to 60°C to enhance the rate of biotic and abiotic contaminant dechlorination, respectively (ESTCP, 2012). Electrical resistance heating is a type of In Situ Thermal Treatment.

Incineration "is the process of burning hazardous materials at temperatures high enough to destroy contaminants. An incinerator is a type of furnace designed for burning hazardous materials in a

combustion chamber…Hazardous materials must be excavated or pumped into containers before incineration. They may require further preparation, such as grinding or removing large rocks and debris, or removing excess water. The materials are then placed in the combustion chamber of an incinerator where they are heated to an extremely high temperature for a specified period of time. The temperature and length of time depend on the types of wastes and contaminants present. Air or pure oxygen may be added to the chamber to supply the oxygen needed for burning…Depending on the contaminants present, the target temperature may range from 1,600 to 2,500°F [870 to 1,370°C]….

"As the wastes heat up, the contaminants volatilize (change into gases) and most are destroyed. Gases that are not destroyed pass through a secondary combustion chamber for further heating and destruction. The resulting gases then pass though air pollution control equipment….

"Incinerators can be constructed for temporary use at the site. However, in recent years, it has been more common for the wastes to be loaded onto trucks for transport to a permanent offsite facility. EPA requires that an incinerator can destroy and remove at least 99.99 percent of each harmful chemical in the waste it processes. When some extremely harmful chemicals are present, EPA requires that an incinerator show it can destroy and remove at least 99.9999 percent of contaminants in the waste" (EPA, 2021g).

In Situ Thermal Treatment (ISTT) "methods heat contaminated soil, and sometimes nearby groundwater, to high temperatures. The heat vaporizes (evaporates) the chemicals and water, changing them into gases… [which] can move more easily through soil than liquids. High temperatures also can destroy some chemicals …Wells pull the chemical and water vapors to the ground surface for aboveground treatment using one of several cleanup methods available [such as, SVE]" (EPA, 2021f). Lower energy ISTT (see Electrical Resistance Heating) can enhance biotic or abiotic contaminant destruction. Specific types of ISTT techniques include conductive heating, electrical resistive heating, radio frequency heating, hot air injection, hot water injection, and steam enhanced extraction.

In Situ Thermal Desorption — See In Situ Thermal Treatment.

Open Burn and Open Detonation operations "are conducted to destroy excess, obsolete, or unserviceable munitions and energetic materials. In [open burn] operations, energetics or munitions are destroyed by self-sustained combustion, which is ignited by an external source, such as a flame, heat, or a detonation wave…In [open detonation] operations, detonatable explosives and munitions are destroyed by detonation, which is generally initiated by the detonation of an energetic charge" (FRTR, 2022).

Steam Enhanced Extraction "injects steam underground by pumping it through wells drilled in the contaminated area. The steam heats the area and vaporizes contaminants" (EPA, 2021f). Steam enhanced extraction is a type of In Situ Thermal Treatment.

Thermal Conduction Heating "uses heaters placed in underground steel pipes. [Thermal conduction heating] heats the contaminated area hot enough to vaporize and even destroy some chemicals" (EPA, 2021f). Thermal conduction heating is a type of In Situ Thermal Treatment.

Thermal Desorption "removes organic contaminants by heating them so that they un-stick (desorb) from soil, sludge or sediment. The heating is done in a machine called a thermal

desorber, and causes the contaminants to evaporate. Evaporation changes the contaminants into vapors (gases) and separates them from the solid material.... A thermal desorber is not the same as an incinerator, which heats contaminated materials to temperatures high enough to destroy the contaminants.... Thermal desorption involves excavating soil or other contaminated material for treatment in a thermal desorber. The desorber may be assembled at the site for onsite treatment, or the material may be loaded into trucks and transported to an offsite thermal desorption facility. To prepare the soil for treatment, large rocks or debris first must be removed or crushed....If the material is very wet, water may need to be removed to improve treatment....

"The prepared soil is placed in the thermal desorber to be heated. Low-temperature thermal desorption is used to heat the solid material to 200–600°F [90 to 320°C] to treat VOCs. If SVOCs are present, then the soil is heated to 600–1,000°F [320 to 540°C].

"Gas collection equipment captures the vapors, which may require further treatment, such as removal of dust particles. Organic vapors are usually destroyed using a thermal oxidizer, which heats the vapors to temperatures high enough to convert them to carbon dioxide and water vapor...

"Treated soil often can be used to backfill the excavation at the site" (EPA, 2021k). Thermal desorption is an ex situ treatment process. In situ thermal desorption processes were previously discussed as In Situ Thermal Treatment.

Thermally-Enhanced SVE — See In Situ Thermal Treatment.

Vitrification is a thermal treatment process that converts contaminated soil to stable glass and crystalline solids. There are two methods for producing heat for melting the contaminated soil. The older method uses electrodes and electrical resistance to vitrify materials, while the emerging technique uses plasma arc technology.

"In the electrical resistance method, high voltage is applied to electrodes (typically four) placed in the soil. Starter frit (generally graphite) is placed on the soil surface and electrical current heats the soil from the top down to temperatures between 1,400 and 2,000°C [2,550 to 3,650°F].... If the silica content of the soil is sufficiently high, contaminated soil can be converted into glass. Heating vaporizes or pyrolyzes organic contaminants. Most inorganic contaminants are encased in the glass-like monolith that results when the soil cools after treatment" (EPA, 2006). Vitrification may be conducted in situ or ex situ.

B.1.5 Pump and Treat (P&T)

Pump and treat "is a common method for cleaning up groundwater [and other aqueous media] containing chemicals, such as industrial solvents, metals, and fuel oil. [Water is extracted and conveyed] to an aboveground treatment system that removes the contaminants. [P&T] systems also help keep the contaminant plume from spreading by pumping contaminated water toward the wells. This pumping helps prevent contaminants from reaching drinking water wells, wetlands, streams, and other natural resources" (EPA, 2021h). For the purpose of this report, all P&T systems are considered treatment, even if designed to only contain, rather than restore, a contaminated plume.

Activated Carbon Treatment — "Activated carbon is a material used to filter harmful chemicals from contaminated water and air. It is composed of granules of coal, wood, nutshells or other

carbon-rich materials. As contaminated water or air flows through activated carbon, the contaminants sorb (stick) to the surface of the granules and are removed from the water or air. Granular activated carbon or 'GAC' can treat a wide range of contaminant vapors including radon and contaminants dissolved in groundwater, such as fuel oil, solvents, polychlorinated biphenyls (PCBs), dioxins, and other industrial chemicals, as well as radon and other radioactive materials. It even removes low levels of some types of metals from groundwater" (EPA, 2021a).

Ex situ "[a]ctivated carbon treatment generally consists of one or more columns or tanks filled with GAC. Contaminated water or vapors are usually pumped through a column from the top down, but upward flow is possible. As the contaminated water or air flows through the GAC, the contaminants sorb to the outer and inner surfaces of the granules. The water and air exiting the container will be cleaner. Regular testing of exiting water or air is conducted to check contaminant levels. If testing shows that some contaminants remain, the water or air may need to be treated again to meet the treatment levels.

"The GAC will need to be replaced when the available surfaces on the granules are taken up by contaminants and additional contaminants can no longer sorb to them. The 'spent' GAC may be replaced with fresh GAC or 'regenerated' to remove the sorbed contaminants. To regenerate spent GAC, it is usually sent to an offsite facility where it is heated to very high temperatures to destroy the contaminants. If a lot of GAC needs to be regenerated, equipment to heat the GAC and remove the sorbed contaminants can be brought to the site.

"Depending on the site, treated groundwater may be discharged to a nearby stream or river or back underground through injection wells or trenches. A sprinkler system can distribute treated water over the ground surface so that it seeps into the soil. The water also may be discharged to the public sewer system or in some cases, reused for other site activities" (EPA, 2021a).

Air Stripping "is the process of moving air through contaminated water in an aboveground treatment system to remove chemicals called 'volatile organic compounds' or 'VOCs.' VOCs are chemicals that easily evaporate, which means they can change from a liquid to a vapor (a gas). The air passed through contaminated water helps evaporate VOCs faster. The chemical vapors are collected, and either treated or vented outside if VOC levels are low enough. Air stripping is commonly used to treat groundwater as part of the pump and treat cleanup method....

"Air stripping uses either an air stripper or aeration tank to force air through contaminated water and evaporate VOCs...The most common type of air stripper is a packed-column air stripper, which is a tall tank filled with pieces of plastic, steel, or ceramic packing material. Contaminated water is pumped into the top of the tank and sprayed over the top of the packing material. The water trickles downward through the spaces between the materials, forming a thin film of water that increases its exposure to air blown in at the bottom of the tank. [A]n aeration tank removes VOCs by bubbling air into a tank containing only contaminated water" (EPA, 2021b).

Filtration "is the physical process of mechanical separation based on particle size whereby particles suspended in a fluid are separated by forcing the fluid through a porous medium. As fluid passes through the medium, the suspended particles are trapped on the surface of the medium and/or within its body...Ultrafiltration/microfiltration occurs when particles are separated by forcing fluid through a semipermeable membrane. Only the particles whose size are smaller than the openings

of the membrane are allowed to flow through" (FRTR, 2022). Other filtration methods include nanofiltration and reverse osmosis.

Ion Exchange "removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. It involves passing contaminated water through an ion exchange resin so that contaminants exchange on sites on the media, exhausting its capacity. After the resin capacity has been exhausted, resins can be regenerated for re-use" (FRTR, 2022).

Metals Precipitation "from contaminated water involves the conversion of soluble heavy metal salts to insoluble salts that will precipitate. The precipitate can then be removed from the treated water by physical methods such as settling and/or filtration. The process usually requires pH adjustment, addition of a chemical precipitant, and a flocculant (e.g., polymer). Typically, metals precipitate from the solution as hydroxides, sulfides, or carbonates, while oils will adhere to the coagulant…The solubilities of the specific contaminants and the required cleanup standards will dictate the process used. In some cases, process design will allow for the generation of sludges that can be sent to recyclers for metal or oil recovery" (FRTR, 2022).

B.2 On-Site Containment Technologies

For the purpose of this report, containment includes several containment technologies, such as caps, covers, and vertical engineered barriers (VEBs).

Building Sealant refers to in-place sealing and covering of accessible contaminated building materials with a high-performance coating to prevent release of contaminants into the indoor air of residential, commercial, and industrial structures. The common method of applying an encapsulant is by brush, roller, or airless sprayer.

Caps and Cover Systems – "Capping involves placing a cover over contaminated material such as landfill waste or contaminated soil…. Caps do not destroy or remove contaminants. Instead, they isolate them and keep them in place to avoid the spread of contamination…The cap design selected for a site will depend on several factors, including the types and concentrations of contaminants present, the size of the site, the amount of rainfall the area receives, and the future use of the property. One or more layers may be needed. For example, an asphalt cap might be selected to cover low levels of soil contamination on a property whose future reuse requires a parking lot. A cap for a hazardous waste landfill, however, might require several layers, including a vegetative layer, drainage layer, geomembrane, and clay layer to ensure water is kept out of the waste" (EPA, 2021c).

Cap (In situ) for sediment refers to "the placement of a subaqueous covering or cap of clean material over contaminated sediment that remains in place. Caps are generally constructed of granular material, such as clean sediment, sand, or gravel" (EPA, 2005).

Containment Cell (subaqueous) for sediment, also referred to as contained aquatic disposal (CAD), "is a type of subaqueous capping in which the dredged sediment is placed into a natural or excavated depression elsewhere in the water body. A related form of disposal, known as level bottom capping, places the dredged sediment on a level bottom elsewhere in the water body, where it is capped…The depression used in the case of a CAD should provide lateral containment of the contaminated material, and also should have the advantage of requiring less maintenance and being more resistant to erosion than level-bottom capping" (EPA, 2005). CAD is regularly

used for navigational dredging projects (e.g., Boston Harbor, Providence River) and has been selected for several environmental dredging projects where the conditions were conducive to CAD cell construction.

Containment Cell (upland, adjacent) for sediment refers to containment in a confined disposal facility (CDF) either upland or adjacent to the water body. "CDFs are engineered structures enclosed by dikes and designed to retain dredged material. They may be located upland (above the water table), partially in the water near shore, or completely surrounded by water. A CDF may have a large cell for material disposal, and adjoining cells for retention and decantation of turbid, supernatant water. A variety of linings have been used to prevent seepage through the dike walls. The most effective are clay or bentonite-cement slurries, but sand, soil, and sediment linings have also been used... Caps are the most effective way to minimize contaminant loss from CDFs, but selection of proper liner material is also an important control in CDFs. Finally, CDFs require continuous monitoring to ensure structural integrity." (EPA, 1991b).

Evapotranspiration (ET) Covers are alternatives to conventional cap and cover systems. "ET cover systems are designed to rely on the ability of a soil layer to store the precipitation until it is naturally evaporated or is transpired by the vegetative cover. In this respect they differ from more conventional cover designs in that they rely on obtaining an appropriate water storage capacity in the soil rather than...engineered low hydraulic conductivity [barrier components]. ET cover system designs are based on using the hydrological processes (water balance components) at a site, which include the water storage capacity of the soil, precipitation, surface runoff, evapotranspiration, and infiltration. The greater the storage capacity and evapotranspirative properties are, the lower the potential for percolation through the cover system" (EPA, 2011).

Repair (pipe/sewer/tank/structure) involves the repair of subsurface structures, such as pipes, sewer lines, and tanks, to control a source of contamination.

Vertical Engineered Barriers (VEB) are "[walls] built below ground to control the flow of groundwater. VEBs may divert the flow direction of contaminated groundwater to keep it from reaching drinking water wells, wetlands or streams. They also may contain and isolate contaminated soil and groundwater to keep them from mixing with clean groundwater. VEBs differ from permeable reactive barriers in that they do not clean up contaminated groundwater" (EPA, 2021m). Common types of VEBs include slurry walls and sheet pile walls.

B.3 Monitored Natural Attenuation (MNA)

MNA is "the reliance on natural attenuation processes (within the context of a carefully controlled and monitored site cleanup approach) to achieve site-specific remediation objectives within a timeframe that is reasonable compared to that offered by other more active methods. The 'natural attenuation processes' that are at work in such a remediation approach include a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants. When relying on natural attenuation processes for site remediation, EPA prefers those processes that degrade or destroy contaminants. Also, EPA generally expects

that MNA will only be appropriate for sites that have a low potential for contaminant migration" (EPA, 1999).

B.4 Monitored Natural Recovery (MNR) for Sediment

Sediment MNR "[relies] on a wide range of naturally occurring processes to reduce risk [from contaminated sediments] to human and/or ecological receptors. These processes may include physical, biological, and chemical mechanisms that act together to reduce the risk posed by the contaminants....Natural processes that reduce toxicity through transformation or reduce bioavailability through increased sorption are usually preferable as a basis for remedy selection to mechanisms that reduce exposure through natural burial or mixing-in-place because the destructive/sorptive mechanisms generally have a higher degree of permanence. However, many contaminants that remain in sediment are not easily transformed or destroyed. For this reason, risk reduction due to natural burial through sedimentation is more common and can be an acceptable sediment management option. Dispersion is the least preferable basis for remedy selection based on MNR. While dispersion may reduce risk in the source area, it generally increases exposure to contaminants and may result in unacceptable risks to downstream areas or other receiving water bodies....

"The key difference between MNA for ground water and MNR for sediment is in the type of processes most often being relied upon to reduce risk. Transformation of contaminants is usually the major attenuating process for contaminated ground water; however, these processes are frequently too slow for the persistent contaminants of concern in sediment to provide for remediation in a reasonable timeframe. Therefore, isolation and mixing of contaminants through natural sedimentation is the process most frequently relied upon for contaminated sediment" (EPA, 2005).

B.5 Enhanced Monitored Natural Recovery (EMNR) for Sediment

Natural recovery combined with an engineering approach is called Enhanced Monitored Natural Recovery. "In some areas, natural recovery may appear to be the most appropriate remedy, yet the rate of sedimentation or other natural processes is insufficient to reduce risks within an acceptable timeframe. Where this is the case, project managers may consider accelerating the recovery process by engineering means, for example by the addition of a thin layer of clean sediment. This approach is sometimes referred to as 'thin-layer placement' or 'particle broadcasting.' Thin-layer placement normally accelerates natural recovery by adding a layer of clean sediment over contaminated sediment. The acceleration can occur through several processes, including increased dilution through bioturbation of clean sediment mixed with underlying contaminants. Thin-layer placement is typically different than...isolation caps...because it is not designed to provide long-term isolation of contaminants from benthic organisms. While thickness of an isolation cap can range up to several feet, the thickness of the material used in thin layer placement could be as little as a few inches....Clean sediment can be placed in a uniform thin layer over the contaminated area or it can be placed in berms or windrows, allowing natural sediment transport processes to distribute the clean sediment to the desired areas.

"Project managers might also consider the addition of flow control structures to enhance deposition in certain areas of a site" (EPA, 2005).

Note that a layer of clean sediment placed as backfill following dredging or excavation is not considered EMNR.

B.6 Vapor Intrusion Mitigation

Vapor intrusion is the term given to migration of vapor-forming chemicals from any underground source into a structure (e.g., homes, businesses, schools) (EPA, 2015). For example, vapors can enter buildings as a component of soil gas by migrating through cracks, seams, interstices, and gaps in basement floors, walls, or foundations ("adventitious openings") or through intentional openings (e.g., perforations due to utility conduits, sump pits) (EPA, 2015).

As used in this document, mitigation refers to "interim actions taken to reduce or eliminate human exposure to vapor-forming chemicals in a specific building arising from the vapor intrusion pathway" (EPA, 2015). Functionally, mitigation methods can be categorized into two basic strategies: (1) those that seek to prevent or reduce vapor entry into a building (e.g., active depressurization technologies, positive building pressurization, sealing cracks and openings); and (2) those that seek to reduce or eliminate vapors that have entered into a building (e.g., indoor air treatment, interior ventilation). Neither strategy entails reducing the level of vapor-forming contamination in the subsurface source, which refers to remediation.

Active Depressurization Technology "creates a driving force for air flow from the building into the subsurface by lowering the pressure below the slab, thereby reducing vapor intrusion (soil gas entry into a building)" (EPA, 2015). This approach is the most thoroughly studied and demonstrated approach for mitigating vapor intrusion. It consists of a group of methods that site teams can customize to treat different construction features of a building, including sub-slab depressurization, drain tile depressurization, wall depressurization, baseboard depressurization, and sub-membrane depressurization (EPA, 2015). Another active depressurization method involves depressurization of a sewer system. This approach may be effective when the sewer is determined to be a major intrusion pathway (Nielsen and Hvidberg, 2017).

Interior Ventilation — Increasing building ventilation (i.e., increasing the rate at which indoor air is replaced with outdoor air) can reduce the buildup of vapor-forming chemicals within a structure. "Natural ventilation may be accomplished by opening windows, doors, and vents. Forced or mechanical ventilation may be accomplished by using a fan to blow air into or out of the building" (EPA, 2015). Exhausting air from the building will generally contribute to under-pressurization of the building, relative to the subsurface, thereby potentially resulting in an increased rate of soil gas entry (i.e., vapor intrusion), which could lead to *higher* levels of vapors in indoor air unless ambient air entry into the building is increased disproportionately.

Passive Barrier (Impermeable Membrane) Installation involves "placing sheets of 'geomembrane' or strong plastic beneath a building to prevent vapor entry. Vapor barriers are best installed during building construction but can be installed in existing buildings that have crawl spaces" (EPA, 2021l). Spray-on vapor barriers (rubberized asphalt emulsions or epoxy) may also be used (EPA, 2008a).

Passive Soil Depressurization is designed to achieve lower sub-slab air pressure relative to indoor air pressure by use of a vent pipe routed through the conditioned space of a building and venting

to the outdoor air, thereby relying solely on the convective flow of air upward in the vent to draw air from beneath the slab" (EPA, 2008a).

Positive Building Pressurization involves "adjusting the building's heating, ventilation, and air-conditioning system to make the pressure indoors greater than the sub-foundation pressure" (EPA, 2021l). This method is typically used for office buildings and other large structures.

Sealing Cracks and Openings involves filling in adventitious and intentional openings in the building foundation using products such as synthetic rubbers, acrylics, oil-based sealants, asphalt/bituminous products, swelling cement, silicon, epoxy or elastomeric polymers (EPA, 2015). In addition, vapor intrusion can be mitigated by "filling cracks in the floor slab and gaps around pipes and utility lines in basement walls or pouring concrete over unfinished dirt floors" (EPA, 2021l).

Soil Pressurization systems "are used to push air into the soil or venting layer below the slab instead of pulling it out. The intention is to increase the sub-slab air pressure above ambient levels, forcing soil gas from the subsurface to the sides of the building." (ITRC, 2007).

Sub-slab Ventilation refers to engineered controls that function by diluting the vapor concentrations beneath the slab and foundation (EPA, 2008a) by drawing outside air into and through the sub-slab area. When installed during building construction, sub-slab ventilation systems "typically consist of: a venting layer (e.g., filled with porous media such as sand or pea gravel; or suitably fabricated with continuous voids) below a floor slab to allow soil gas to move laterally to a collection piping system for discharge to the atmosphere; and a sub-slab liner that is installed on top of the venting layer to reduce entry points for vapor intrusion" (EPA, 2015).

B.7 Other or Unspecified Remedies

Alternative Water Supply Remedy — "In CERCLA, section 101(34) states that '[t]he term 'alternative water supplies' includes, but is not limited to, drinking water and household water supplies.' Also, CERCLA section 118 states that in taking response actions, the President [EPA] shall 'give a high priority to facilities where the release of hazardous substances or pollutants or contaminants has resulted in the closing of drinking water wells or has contaminated a principal drinking water supply.'...Providing an alternative supply of water to affected users generally is designed to prevent residents from being exposed to contaminated groundwater...Providing an alternative water supply may involve furnishing clean, drinkable water on a permanent or temporary basis. For example, providing a permanent supply of drinking water may include installing a private well, connecting to a municipal water system, drilling of a new community water supply well, or reinstating a previously contaminated water supply well once the groundwater has been cleaned up. Examples of providing a temporary supply of water may involve installing individual treatment units or delivering bottled water. When a [Superfund] response action that provides an alternative water supply involves connecting hundreds of homes to a municipal system (i.e., a residential connection to a water purveyor), it generally means that [residents are connected] to a water supply line that is located relatively close by" (EPA, 2010).

Fracturing for Site Cleanup — "Fracturing creates or enlarges openings in rock or dense soil, such as clay, to help soil and groundwater cleanup methods work better. The openings, called 'fractures,' become pathways through which contaminants in soil and groundwater can be treated

'in situ' (in place) by injection or pumped aboveground for treatment. Although fractures can occur naturally in soil and rock, they are not always wide or long enough to easily reach underground contamination using cleanup methods. Fracturing can enlarge the cracks and create new ones to improve the speed and effectiveness of the cleanup" (EPA, 2021d).

Fracturing for site cleanup is different from fracturing to recover oil and gas. "Oil and gas hydraulic fracturing is used to stimulate the recovery of oil or natural gas from underground geologic formations. Oil and gas hydraulic fracturing works by pumping a mixture of fluids and other substances into the target formation to create and enlarge fractures. Such operations are much larger, use different equipment and chemical additives, occur at greater depths, and use higher volumes of fluid than fracturing for site cleanup. Fracturing to clean up a contaminated site rarely exceeds a depth of 100 feet, and the affected area around the fracturing well usually is less than 100 feet in any direction. However, wells to extract oil and gas often are drilled hundreds or thousands of feet downward and sometimes horizontally into the oil- or gas-bearing rock. Fractures may extend over 500 feet from these wells" (EPA, 2021d).

Institutional Controls (ICs) are defined by EPA as "non-engineered instruments, such as administrative and legal controls, that help to minimize the potential for human exposure to contamination and/or protect the integrity of a response action. ICs typically are designed to work by limiting land and/or resource use or by providing information that helps modify or guide human behavior at a site. ICs are a subset of Land Use Controls..., [which] include engineering and physical barriers, such as fences and security guards, as well as ICs" (EPA, 2021n). Some common examples of ICs include zoning restrictions, building or excavation permits, well drilling prohibitions, easements, and covenants.

Soil Amendments — "Many soils, particularly those found in urban, industrial, mining, and other disturbed areas, suffer from a range of physical, chemical, and biological limitations. They include soil toxicity, too high or too low pH, lack of sufficient organic matter, reduced water-holding capacity, reduced microbial communities, and compaction. Appropriate soil amendments may be inorganic (e.g., liming materials), organic (e.g., composts) or mixtures (e.g., lime-stabilized biosolids). When specified and applied properly, these beneficial soil amendments may limit many of the exposure pathways and reduce soil phytotoxicity. Soil amendments also can restore appropriate soil conditions for plant growth by balancing pH, adding organic matter, restoring soil microbial activity, increasing moisture retention, and reducing compaction." (EPA, 2007).

Wetlands Replacement — "Compensatory mitigation is required to replace the loss of wetland and aquatic resource functions in [a] watershed. Compensatory mitigation refers to the restoration, establishment, enhancement, or in certain circumstances preservation of wetlands, streams or other aquatic resources for the purpose of offsetting unavoidable adverse impacts [from a specific project]" (EPA, 2008c). For the purposes of this report, mitigation performed at the site of the adverse impacts is excluded from the definition of wetlands replacement. For mitigation performed at the site of adverse impacts, see Wetlands Restoration. For wetlands constructed as a form of treatment, see Constructed Treatment Wetlands.

Wetlands Restoration is defined as "[r]e-establishment or rehabilitation of a wetland or other aquatic resource with a goal of returning natural or historic functions and characteristics to a former or degraded wetland" (EPA, 2008c). For the purposes of this report, restoration conducted

at a location other than the impacted site is excluded from the definition of wetlands restoration and is instead considered Wetlands Replacement. For wetlands constructed as a form of treatment, see Constructed Treatment Wetlands.

Appendix C

Individual Contaminants and Assigned Contaminant Groups

Appendix C: Individual Contaminants and Assigned Contaminant Groups

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
(2-METHYL-2-PROPANYL)BENZENE		X									X						
(2Z)-2-BUTENEDIOIC ACID				X									X				
(3R)-1-AZABICYCLO[2.2.2]OCTAN-3-YL HYDROXY(DIPHENYL)ACETATE				X									X				
(4-CHLORO-2-METHYLPHENOXY)ACETIC ACID		X												X			
(E)-1,3-DICHLORO-1-PROPENE			X				X										
(Z)-1,3-DICHLORO-1-PROPENE			X				X										
[(E)-PROP-1-ENYL]BENZENE				X									X				
1,1,1,2-TETRACHLOROETHANE			X				X										
1,1,1-TRICHLOROETHANE			X				X										
1,1,2,2-TETRABROMOETHANE			X				X										
1,1,2,2-TETRACHLORO-1,2-DIFLUOROETHANE			X				X										
1,1,2,2-TETRACHLOROETHANE			X				X										
1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE			X				X										
1,1,2-TRICHLOROETHANE			X				X										
1,1'-BIPHENYL			X				X										
1,1-DICHLOROETHANE			X				X										
1,1-DICHLOROETHENE			X				X										
1,2,3,4,6,7,8,9-OCTACHLORODIBENZO[b,e][1,4]DIOXIN (OCDD)		X				X											
1,2,3,4,6,7,8,9-OCTACHLORODIBENZOFURAN		X				X											
1,2,3,4,6,7,8-HEPTACHLORODIBENZO[b,e][1,4]DIOXIN (HpCDD)		X				X											
1,2,3,4,6,7,8-Heptachlorodibenzofuran		X				X											
1,2,3,4,7,8,9-Heptachlorodibenzofuran		X				X											
1,2,3,4,7,8-HEXACHLORODIBENZO[b,e][1,4]DIOXIN (HxCDD)		X				X											
1,2,3,4,7,8-HEXACHLORODIBENZOFURAN (HxCDF)		X				X											
1,2,3,4-TETRACHLOROBENZENE		X							X								
1,2,3,6,7,8-HEXACHLORODIBENZO[b,e][1,4]DIOXIN (HxCDD)		X				X											
1,2,3,6,7,8-HEXACHLORODIBENZOFURAN (HxCDF)		X				X											
1,2,3,7,8,9-HEXACHLORODIBENZOFURAN (HxCDF)		X				X											
1,2,3,7,8,9-HEXACHLORODIBENZO-p-DIOXIN (HxCDD)		X				X											
1,2,3,7,8-PENTACHLORODIBENZO[b,e][1,4]DIOXIN (PeCDD)		X				X											
1,2,3,7,8-PENTACHLORODIBENZOFURAN		X				X											
1,2,3-TRICHLOROBENZENE		X							X								
1,2,3-TRICHLOROPROPANE			X				X										
1,2,3-TRIMETHYLBENZENE			X									X					

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
1,2,4,5-TETRACHLOROBENZENE		X							X								
1,2,4-TRICHLOROBENZENE		X							X								
1,2,4-TRIMETHYLBENZENE			X									X					
1,2-DIBROMO-3-CHLOROPROPANE		X												X			
1,2-DIBROMOETHANE			X				X										
1,2-DICHLORO-1,1,2,2-TETRAFLUOROETHANE			X				X										
1,2-DICHLOROBENZENE			X				X										
1,2-DICHLOROETHANE			X				X										
1,2-DICHLOROETHENE (CIS AND TRANS MIXTURE)			X				X										
1,2-DICHLOROPROPANE			X				X										
1,2-DIHYDROACENAPHTHYLENE		X															X
1,2-DIMETHYLBENZENE (O-XYLENE)			X		X												
1,2-DIPHENYLHYDRAZINE		X									X						
1,2-ETHANEDIOL (ETHYLENE GLYCOL)		X									X						
1,2-PROPANEDIOL		X									X						
1,3 (OR 1,4)-DIMETHYLBENZENE (M (OR P)-XYLENE)			X		X												
1,3,5,7-TETRANITRO-1,3,5,7-TETRAZOCANE (HMX)		X									X						
1,3,5-TRICHLOROBENZENE		X							X								
1,3,5-TRIMETHYLBENZENE			X									X					
1,3,5-TRINITROBENZENE		X									X						
1,3-BENZENEDIOL		X									X						
1,3-BUTADIENE			X									X					
1,3-DICHLOROBENZENE			X				X										
1,3-DICHLOROPROPENE (EZ MIXTURE)			X				X										
1,3-DIMETHYLBENZENE (M-XYLENE)			X		X												
1,3-DINITROBENZENE		X									X						
1,3-DIOXO-1,3-DIHYDRO-2-BENZOFURAN-5-CARBOXYLIC ACID				X									X				
1,4-BENZENEDICARBOXYLIC ACID				X									X				
1,4-DICHLOROBENZENE			X				X										
1,4-DIMETHYLBENZENE (P-XYLENE)			X		X												
1,4-DIOXANE			X									X					
1,4-DITHIANE			X				X										
10-CHLORO-5H-PHENARSAZININE				X									X				
10H-PHENOTHIAZINE				X									X				

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
1-BROMO-4-PHENOXYBENZENE		X							X								
1-BUTANOL (N-BUTANOL)			X									X					
1-BUTOXYBUTANE			X									X					
1-CHLORO-2-[(2-CHLOROETHYL)SULFANYL]ETHANE			X				X										
1-CHLORO-2-ETHENOXYETHANE			X				X										
1-CHLORO-2-METHYLBENZENE (O-CHLOROTOLUENE)			X				X										
1-CHLORO-4-PHENOXYBENZENE		X							X								
1H-INDENE		X															X
1-METHYL-2-NITROBENZENE		X									X						
1-METHYL-3-NITROBENZENE		X									X						
1-METHYL-4-NITROBENZENE		X									X						
1-METHYL-4-PROPAN-2-YLBENZENE		X									X						
1-METHYLNAPHTHALENE		X															X
1-NITROSOPYRROLIDINE		X									X						
1-PHENYLETHANONE		X									X						
1-PROPENE			X									X					
2-(1-METHYLPROPYL)-4,6-DINITROPHENOL (DINOSEB)		X												X			
2-(2,4,5-TRICHLOROPHENOXY)PROPANOIC ACID		X												X			
2-(2,4-DICHLOROPHENOXY)PROPANOIC ACID		X												X			
2,2',2''-NITRILOTRIETHANOL			X									X					
2,2,2-TRICHLORO-1,1-BIS(4-CHLOROPHENYL)ETHANOL		X												X			
2,2,4-TRIMETHYLPENTANE			X									X					
2,2-DICHLOROETHENYL DIMETHYL PHOSPHATE		X												X			
2,2'-OXYDIETHANOL				X									X				
2,3,4,6,7,8-Hexachlorodibenzofuran		X				X											
2,3,4,7,8-PENTACHLORODIBENZOFURAN (PeCDF)		X				X											
2,3,5,6-TETRACHLOROPHENOL		X							X								
2,3,7,8-TETRACHLORODIBENZOFURAN		X				X											
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN (TCDD)		X				X											
2,3,7,8-TETRACHLORODIBENZO-p-DIOXIN (TCDD) TOXICITY EQUIVALENTS (TEq)		X				X											
2,4,4-Trimethyl-1-pentene			X									X					
2,4,4-Trimethyl-2-pentene			X									X					
2,4,5-TRICHLOROPHENOL		X							X								
2,4,5-TRICHLOROPHENOXYACETIC ACID		X												X			

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
2,4,6-TRICHLOROPHENOL		X							X								
2,4,6-TRINITROPHENOL		X									X						
2,4,6-TRINITROTOLUENE		X									X						
2,4-DICHLOROPHENOL		X							X								
2,4-DICHLOROPHENOXYACETIC ACID		X												X			
2,4-DIMETHYLPHENOL		X							X								
2,4-DINITROPHENOL		X							X								
2,4-DINITROTOLUENE		X									X						
2,5-NORBORNADIENE		X									X						
2,6-DINITROTOLUENE		X									X						
2-[FLUORO(METHYL)PHOSPHORYL]OXYPROPANE (SARIN)			X				X										
2-AMINO-4,6-DINITROTOLUENE		X									X						
2-AMINOPYRIDINE				X									X				
2-BENZOFURAN-1,3-DIONE		X									X						
2-BUTANONE (METHYL ETHYL KETONE)			X									X					
2-BUTOXYETHANOL				X									X				
2-CHLORO-1-PHENYLETHANONE				X									X				
2-CHLOROANILINE		X							X								
2-CHLORONAPHTHALENE		X							X								
2-CHLOROPHENOL		X							X								
2-ETHOXYETHANOL			X									X					
2-FLUOROACETIC ACID		X												X			
2-HEXANONE			X									X					
2-HYDROXY-2,2-DIPHENYLACETIC ACID				X						X							
2-METHOXY-2-METHYLPROPANE (MTBE)			X									X					
2-METHYL-1,3-BUTADIENE			X									X					
2-METHYL-2-PROPANOL			X									X					
2-METHYL-4,6-DINITROPHENOL (4,6-DINITRO-O-CRESOL)		X							X								
2-METHYLANILINE		X									X						
2-METHYLNAPHTHALENE		X															X
2-METHYLOXIRANE			X									X					
2-METHYLPHENOL (O-CRESOL)		X							X								
2-METHYLPROP-2-ENENITRILE			X									X					
2-NAPHTHALENAMINE		X									X						

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
2-NITROANILINE		X									X						
2-NITROPHENOL		X							X								
2-PROPAN-2-YLOXYPROPANE			X									X					
2-PROPANOL			X									X					
2-PROPENENITRILE (ACRYLONITRILE)			X									X					
3-(3,4-DICHLOROPHENYL)-1,1-DIMETHYLUREA (DIURON)		X												X			
3-(4-CHLOROPHENYL)-1,1-DIMETHYLUREA		X												X			
3,5,5-TRIMETHYLCYCLOHEX-2-EN-1-ONE		X									X						
3,6-DICHLORO-2-METHOXYBENZOIC ACID		X												X			
3-CHLOROANILINE		X							X								
3-METHYLPHENOL (M-CRESOL)		X							X								
3-METHYLPHENOL (MIXED MONOCHLORINATED ISOMERS)		X							X								
3-NITROANILINE		X									X						
4-(2,4-DICHLOROPHENOXY)BUTANOIC ACID		X												X			
4-(4-AMINO-3-CHLOROPHENYL)-2-CHLOROANILINE		X							X								
4-(4-AMINO-3-METHYLPHENYL)-2-METHYLANILINE		X									X						
4,4'-METHYLENEBIS(2-CHLOROANILINE)		X							X								
4-AMINO-2,6-DINITROTOLUENE		X									X						
4-CHLORO-3-METHYLPHENOL		X							X								
4-CHLOROANILINE		X							X								
4-CYANO-1,2,3,4-TETRAHYDRO-1-NAPHTHALENE-PROPIONITRILE		X									X						
4-CYANO-1,2,3,4-TETRAHYDRO-ALPHA-METHYL-1-NAPHTHALENEACETONITRILE		X									X						
4-METHOXYPHENOL		X							X								
4-METHYL-2-PENTANONE (METHYL ISOBUTYL KETONE)			X									X					
4-METHYLCHRYSENE		X															X
4-METHYLHEPTYL 2-(2,4,5-TRICHLOROPHENOXY)PROPANOATE		X												X			
4-METHYLPHENOL (P-CRESOL)		X							X								
4-NITROANILINE		X									X						
4-NITROPHENOL		X							X								
4-NITROSODIPHENYLAMINE		X									X						
4-PHENYLANILINE		X									X						
9H-CARBAZOLE		X									X						
9H-FLUORENE		X															X
ACENAPHTHYLENE		X															X

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
ACETONE			X									X					
ACETONITRILE			X									X					
ACROLEIN			X									X					
ACRYLAMIDE		X												X			
ACTINIUM-227	X							X									
ACTINIUM-228	X							X									
ALACHLOR		X												X			
ALDRIN		X												X			
ALPHA GROSS				X						X							
ALPHA-CHLORDANE		X												X			
ALPHA-HEXACHLOROCYCLOHEXANE		X												X			
ALUMINUM	X							X									
ALUMINUM OXIDE	X							X									
AMERICIUM	X							X									
Americium-241	X							X									
AMMONIA				X						X							
AMMONIUM HYDROXIDE				X						X							
AMMONIUM NITRATE				X						X							
AMMONIUM TETRACHLOROZINCATE				X						X							
ANILINE		X									X						
ANTHANTHRENE		X															X
ANTHRACENE		X															X
ANTIMONY	X							X									
ANTIMONY COMPOUNDS	X							X									
AROCLOR 1016		X													X		
AROCLOR 1221		X													X		
AROCLOR 1232		X													X		
AROCLOR 1242		X													X		
AROCLOR 1248		X													X		
AROCLOR 1254		X													X		
AROCLOR 1260		X													X		
AROCLOR 1262		X													X		
Aroclor 1268		X													X		
ARSENIC	X							X									

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
ARSENIC COMPOUNDS	X							X									
ASBESTOS				X						X							
ATRAZINE		X												X			
AZEPAN-2-ONE				X									X				
AZOBENZENE		X									X						
AZULENE		X															X
BARIUM	X							X									
BARIUM CHLORIDE				X						X							
BARIUM COMPOUNDS	X							X									
BENZALDEHYDE			X									X					
BENZENE			X		X												
BENZIDINE		X									X						
BENZIDINE AND ITS SALTS		X									X						
BENZO(B)FLUORANTHENE		X															X
BENZO(GHI)PERYLENE		X															X
BENZO(K)FLUORANTHENE		X															X
BENZO[A]ACEANTHRYLENE		X															X
BENZO[A]ANTHRACENE		X															X
BENZO[A]PYRENE		X															X
BENZO[A]PYRENE EQUIVALENTS (BaPEq)		X															X
BENZO[E]PYRENE		X															X
BENZO[J]FLUORANTHENE		X															X
BENZOIC ACID		X									X						
BENZONITRILE			X									X					
BENZOPHENONE			X									X					
BENZOYL BENZENECARBOPEROXOATE				X									X				
BENZOYL CHLORIDE			X				X										
BERYLLIUM	X							X									
BERYLLIUM COMPOUNDS	X							X									
BETA GROSS				X						X							
BETA-HEXACHLOROCYCLOHEXANE		X												X			
BIS(2-CHLOROETHOXY) METHANE		X							X								
BIS(2-CHLOROETHYL)ETHER		X							X								
BIS(2-CHLOROISOPROPYL) ETHER		X							X								

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
BIS(2-ETHYLHEXYL) ADIPATE				X									X				
BIS(2-ETHYLHEXYL)PHTHALATE		X									X						
BIS(CHLOROMETHYL) ETHER			X				X										
BISMUTH	X							X									
BISMUTH TEILLURIDE				X						X							
BISMUTH-211	X							X									
BISMUTH-212	X							X									
BISMUTH-214	X							X									
BORON	X							X									
BORON OXIDE				X						X							
BROMACIL		X												X			
BROMINE (BR2)				X						X							
BROMINE-CONTAINING INORGANIC COMPOUNDS				X						X							
BROMOCHLOROMETHANE			X				X										
BROMODICHLOROMETHANE			X				X										
BROMOFORM			X				X										
BROMOMETHANE			X				X										
BUTAN-2-YLBENZENE			X									X					
BUTYL ACETATE			X									X					
BUTYL BENZYL PHTHALATE		X									X						
BUTYLATE		X												X			
BUTYLBENZENE			X									X					
BUTYLTIN TOXICITY EQUIVALENTS (TEq)				X									X				
C.I. ACID GREEN 3				X									X				
C.I. BASIC VIOLET 1				X									X				
C11-C22 Aromatic Hydrocarbons		X											X				
C13-C18 Aliphatic Hydrocarbons		X											X				
C19-C36 ALIPHATIC HYDROCARBONS		X											X				
C5-C8 Aliphatic Hydrocarbons		X											X				
C9-C10 Aromatic Hydrocarbons		X											X				
C9-C12 Aliphatic Hydrocarbons		X											X				
C9-C18 ALIPHATIC HYDROCARBONS		X											X				
CADMIUM	X							X									
CALCIUM	X							X									

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
CALCIUM CARBONATE				X						X							
CALCIUM OXIDE				X						X							
CAMPHOR				X									X				
CARBARYL		X												X			
CARBOFURAN		X												X			
CARBON DISULFIDE			X									X					
CARBON TETRACHLORIDE			X				X										
CARBON-14				X						X							
CARBONYL DICHLORIDE (PHOSGENE)				X						X							
CARBOPHENOTHION		X												X			
CARCINOGENIC POLYCYCLIC AROMATIC HYDROCARBONS (cPAH)		X															X
CESIUM	X							X									
CESIUM-134	X							X									
CESIUM-137	X							X									
CHLORDANE		X												X			
CHLORDECONE		X												X			
CHLORENDIC ACID				X									X				
CHLORIDE				X						X							
CHLORINATED DIOXINS AND FURANS		X				X											
CHLORINE (CL2)				X						X							
CHLOROACETIC ACID		X												X			
CHLOROBENZENE			X				X										
CHLOROBENZILATE		X												X			
CHLOROBENZOIC ACID		X												X			
CHLOROETHANE			X				X										
CHLOROETHENE (VINYL CHLORIDE)			X				X										
CHLOROFORM			X				X										
CHLOROMETHANE			X				X										
CHLOROMETHYLBENZENE			X				X										
CHLOROPHENOXY HERBICIDES		X												X			
CHLORPYRIFOS		X												X			
CHROMIC ACID				X						X							
CHROMIUM	X							X									
CHROMIUM (HEXAVALENT COMPOUNDS)	X							X									

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
CHROMIUM (III)	X							X									
CHROMIUM COMPOUNDS	X							X									
CHROMIUM(III) CHLORIDE				X						X							
CHROMIUM(III) SULFATE				X						X							
CHROMIUM(VI)	X							X									
CHRYSENE		X															X
CIS-1,2-DICHLOROETHENE			X				X										
COBALT	X							X									
COBALT-57	X							X									
COBALT-60	X							X									
COPPER	X							X									
COPPER COMPOUNDS	X							X									
COUMAPHOS		X												X			
CREOSOTE		X															X
CRESOL (MIXED ISOMERS)		X									X						
CUMENE			X									X					
CURIUM	X							X									
CYANIDE				X						X							
CYANIDE COMPOUNDS				X						X							
CYANIDES, INORGANIC SALTS				X						X							
CYCLOHEXANE			X									X					
CYCLOHEXANOL			X									X					
CYCLOHEXANONE			X									X					
DDT AND METABOLITES		X												X			
DELTA-HEXACHLOROCYCLOHEXANE		X												X			
DEMEPHION-S		X												X			
DIAMINOTOLUENE (MIXED ISOMERS)		X									X						
DIAZINON		X												X			
DIBENZ[A,H]ACRIDINE		X															X
DIBENZ[A,J]ANTHRACENE		X															X
DIBENZO(A,H)ANTHRACENE		X															X
DIBENZO[A,E]PYRENE		X															X
DIBENZO[A,H]PYRENE		X															X
DIBENZOFURAN		X									X						

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
DIBROMOCHLOROMETHANE			X				X										
DIBROMOMETHANE			X				X										
DIBUTYL PHTHALATE		X									X						
DICHLORO-[(E)-2-CHLOROETHENYL]ARSANE (LEWISITE)	X							X									
DICHLOROBENZENE (MIXED ISOMERS)			X				X										
DICHLORODIFLUOROMETHANE			X				X										
DICHLOROMETHANE (METHYLENE CHLORIDE)			X				X										
DICHLOROMONOFLUOROMETHANE			X				X										
DICHLOROPROPANE (MIXED ISOMERS)			X				X										
DICYCLOPENTADIENE		X									X						
DIELDRIN		X												X			
DIESEL FUEL		X											X				
DIESEL RANGE ORGANICS		X											X				
DIETHYL ETHER			X									X					
DIETHYL PHTHALATE		X									X						
DIETHYLBENZENE (MIXED ISOMERS)		X									X						
DIMETHOXYMETHANE			X									X					
DIMETHYL ETHYL BENZENE (MIXED ISOMERS)			X									X					
DIMETHYL PHENOL (MIXED ISOMERS)		X									X						
DIMETHYL PHTHALATE		X									X						
DIMETHYL SULFIDE				X									X				
DIMETHYLFORMAMIDE		X												X			
DIMETHYLMERCURY			X									X					
DINITROTOLUENE (MIXED ISOMERS)		X									X						
DI-N-OCTYL PHTHALATE		X									X						
DIOXINS (CHLORINATED DIBENZODIOXINS)		X				X											
DIOXINS AND DIBENZOFURANS		X				X											
DIPHENAMID		X												X			
DIPHENYLAMINE		X									X						
DISULFOTON		X												X			
ENDOSULFAN (I OR II)		X												X			
ENDOSULFAN I		X												X			
ENDOSULFAN II		X												X			
ENDOSULFAN SULFATE		X												X			

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
ENDRIN		X												X			
ENDRIN ALDEHYDE		X												X			
ENDRIN KETONE		X												X			
ETHANE			X									X					
ETHANE-1,2-DIAMINE		X												X			
ETHANETHIOL			X									X					
ETHANOL			X									X					
ETHION		X												X			
ETHYL ACETATE			X									X					
ETHYL CARBONOCHLORIDATE			X				X										
ETHYL METHYL BENZENE (MIXED ISOMERS)			X									X					
ETHYL PROP-2-ENOATE			X									X					
ETHYLBENZENE			X		X												
EUROPIUM	X							X									
EUROPIUM-152	X							X									
Europium-154	X							X									
EUROPIUM-155	X							X									
FENSULFOTHION		X												X			
FLUORANTHENE		X															X
FLUORIDE				X						X							
FLUORINE (F2)				X						X							
FONOFOS		X												X			
FORMALDEHYDE			X									X					
FORMIC ACID			X									X					
FORMOTHION		X												X			
FURAN		X				X											
GAMMA RADIOACTIVITY EMITTERS				X						X							
GAMMA-CHLORDANE		X												X			
GAMMA-HEXACHLOROCYCLOHEXANE (LINDANE)		X												X			
GASOLINE		X											X				
GUTHION		X												X			
Halogenated VOCs			X				X										
HEAVY METALS	X							X									
HEPTACHLOR		X												X			

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
HEPTACHLOR EPOXIDE		X												X			
HEPTACHLORODIBENZO[b,e][1,4]DIOXIN (HpCDD) (MIXED ISOMERS)		X				X											
HEPTANE			X									X					
HEXABROMOBIPHENYL				X									X				
HEXACHLORO-1,3-BUTADIENE		X							X								
HEXACHLOROBENZENE		X												X			
HEXACHLOROCYCLOPENTADIENE		X												X			
HEXACHLORODIBENZO[b,e][1,4]DIOXIN (HxCDD) (MIXED ISOMERS)		X				X											
HEXACHLOROETHANE		X							X								
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE (RDX)		X									X						
HEXANE			X									X					
HYDRAZINE				X						X							
HYDROCARBONS		X											X				
HYDROGEN (H2)				X						X							
HYDROGEN CARBONATE				X						X							
HYDROGEN CHLORIDE				X						X							
HYDROGEN CYANIDE				X						X							
HYDROGEN FLUORIDE				X						X							
HYDROGEN SULFIDE				X						X							
INDENO(1,2,3-CD)PYRENE		X															X
INDIUM	X							X									
INORGANICS				X						X							
IODINE (I2)				X						X							
IODINE-129				X						X							
IRON	X							X									
ISODRIN		X												X			
KEROSENE		X											X				
LEAD	X							X									
LEAD COMPOUNDS	X							X									
LEAD COMPOUNDS (INORGANIC)	X							X									
LEAD(II) ACETATE			X									X					
LEAD-210	X							X									
LEAD-211	X							X									
LEAD-212	X							X									

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
LEAD-214	X							X									
LINURON		X												X			
LITHIUM	X							X									
MAGNESIUM	X							X									
MALATHION		X												X			
MANGANESE	X							X									
MANGANESE COMPOUNDS	X							X									
MANGANESE-54	X							X									
MECOPROP		X												X			
MERCURY	X							X									
MERCURY COMPOUNDS	X							X									
MERCURY(II) CHLORIDE	X							X									
METALS	X							X									
METHANE			X									X					
METHANETHIOL			X									X					
METHANOL			X									X					
METHIOCARB		X												X			
METHOXYCHLOR		X												X			
METHYL 2-METHYLPROP-2-ENOATE			X									X					
METHYL ACETATE			X									X					
METHYL MERCURY	X							X									
METHYL PARATHION		X												X			
METHYL PROP-2-ENOATE			X									X					
METHYLCYCLOHEXANE			X									X					
METHYLCYCLOHEXANOL (MIXED ISOMERS)			X									X					
METHYLMERCURY DICYANDIAMIDE		X												X			
METHYLPHENOL (CRESOL MIXED ISOMERS)		X									X						
METHYLPHOSPHONIC ACID				X									X				
MEVINPHOS		X												X			
MINERAL OILS		X									X						
MIREX		X												X			
MOLINATE		X												X			
MOLYBDENUM	X							X									
MONOCROTOPHOS		X												X			

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
N,N-BIS(2-CHLOROETHYL)-2-NAPHTHALENAMINE				X									X				
N,N-DIBUTYLNITROUS AMIDE		X									X						
N,N-DIETHYLNITROUS AMIDE		X									X						
N,N-DIMETHYLANILINE		X									X						
N,N-DIPHENYLNITROUS AMIDE		X									X						
N,N-DIPROPYLNITROUS AMIDE		X									X						
NAPHTHALENE		X															X
NAPHTHENIC ACIDS				X									X				
NEODYMIUM	X							X									
NEPTUNIUM	X							X									
NICKEL	X							X									
NICKEL-63	X							X									
NITRATE				X						X							
NITRATE/NITRITE				X						X							
NITRITE				X						X							
NITROAROMATICS		X									X						
NITROBENZENE		X									X						
NITROGEN				X						X							
NITROGLYCERIN		X									X						
NITROTOLUENE (MIXED ISOMERS)		X									X						
N-METHYL-N,2,4,6-TETRANITROANILINE (TETRYL)		X									X						
N-NITROSODIMETHYLAMINE		X									X						
NONANE		X									X						
O,O,O,O-TETRAETHYL DITHIODIPHOSPHATE		X												X			
OCTANE			X									X					
O-DINITROBENZENE		X									X						
O-ETHYL O-(4-NITROPHENYL) PHENYLPHOSPHONOTHIOATE		X												X			
O-ETHYL S,S-DIPROPYL PHOSPHORODITHIOATE (ETHOPROP)		X												X			
ORGANICS				X									X				
OXAMYL		X												X			
P,P'-DDD		X												X			
P,P'-DDE		X												X			
P,P'-DDT		X												X			
PARATHION		X												X			

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
p-CYMENE		X									X						
PEBULATE		X												X			
PENDIMETHALIN		X												X			
PENTACHLOROBENZENE		X							X								
PENTACHLORODIBENZO[b,e][1,4]DIOXIN (PECDD) (MIXED ISOMERS)		X				X											
PENTACHLORODIBENZOFURAN (PeCDF)		X				X											
PENTACHLOROETHANE			X				X										
PENTACHLORONITROBENZENE		X							X								
PENTACHLOROPHENOL		X												X			
PENTAERYTHRITOL TETRANITRATE (PETN)		X									X						
PENTANE			X									X					
Per- and Polyfluoroalkyl Substances (PFAS)		X														X	
PERCHLORATE				X						X							
PERFLUOROOCTANE SULFONIC ACID		X														X	
PERFLUOROOCTANOIC ACID (PFOA)		X														X	
PESTICIDES		X												X			
PETROLEUM		X											X				
PHENACETIN		X									X						
PHENANTHRENE		X															X
PHENAZOPYRIDINE				X									X				
PHENOL		X							X								
PHENYLMETHANOL		X									X						
PHORATE		X												X			
PHOSPHORIC ACID				X						X							
PHOSPHORUS				X						X							
PHOSPHORUS (P4)				X						X							
PHOSPHORUS COMPOUNDS				X						X							
PHOTOMIREX		X												X			
PLATINUM	X							X									
PLUTONIUM	X							X									
PLUTONIUM-238	X							X									
PLUTONIUM-239	X							X									
PLUTONIUM-239/240	X							X									
PLUTONIUM-240	X							X									

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
PLUTONIUM-241	X							X									
PLUTONIUM-242	X							X									
PLUTONIUM-244	X							X									
POLONIUM-210	X							X									
POLYBROMINATED BIPHENYLS (FIREMASTER FF 1)				X									X				
POLYCHLORINATED BIPHENYLS (CONTAINING 60 OR MORE PERCENT CHLORINE BY MOLECULAR WEIGHT)		X													X		
POLYCHLORINATED BIPHENYLS (PCBs)		X													X		
POLYCHLORINATED TERPHENYLS		X													X		
POLYCYCLIC AROMATIC HYDROCARBONS (PAHS)		X															X
POLYCYCLIC AROMATIC HYDROCARBONS, HIGH MOLECULAR WEIGHT (HPAHS)		X															X
POLYCYCLIC AROMATIC HYDROCARBONS, LOW MOLECULAR WEIGHT (LPAHS)		X															X
POTASSIUM	X							X									
POTASSIUM CYANIDE				X						X							
POTASSIUM HYDROXIDE				X						X							
POTASSIUM NITRATE	X							X									
POTASSIUM PERMANGANATE				X						X							
POTASSIUM-40	X							X									
PROMETHIUM-147	X							X									
PROMETON		X												X			
PROMETRYN		X												X			
PROPANEDINITRILE			X									X					
PROPYLBENZENE		X									X						
PROTACTINIUM-231	X							X									
PROTACTINIUM-234	X							X									
PYRENE		X															X
PYRIDINE		X									X						
QUINOLINE		X									X						
RADIOACTIVE	X							X									
RADIONUCLIDES	X							X									
RADIUM	X							X									
RADIUM-223	X							X									
RADIUM-224	X							X									
RADIUM-226	X							X									
RADIUM-228	X							X									

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
RADON				X						X							
RADON AND ITS DECAY PRODUCTS				X						X							
RADON-222				X						X							
Residual Range Organics (RRO)		X											X				
RONNEL		X												X			
RUTHENIUM-106	X							X									
SABADILLA				X									X				
SELENIUM	X							X									
S-ETHYL N,N-DIPROPYLCARBAMOTHIOATE (EPTC)		X												X			
SILICON	X							X									
SILICON DIOXIDE (AMORPHOUS SILICA)				X						X							
SILICONE				X						X							
SILVER	X							X									
SIMAZINE		X												X			
SODIUM	X							X									
SODIUM CYANIDE				X						X							
SODIUM HYDROXIDE				X						X							
SODIUM NITRATE				X						X							
SODIUM NITRITE				X						X							
SODIUM-22	X							X									
STODDARD SOLVENT			X									X					
STRONTIUM	X							X									
STRONTIUM-90	X							X									
STYRENE			X									X					
SULFATE				X						X							
SULFIDE			X									X					
SULFUR				X						X							
SULFUR DIOXIDE				X						X							
SULFURIC ACID				X						X							
TANTALUM	X							X									
TECHNETIUM-99	X							X									
TETRABUTYL ORTHOSILICATE				X						X							
TETRACHLORODIBENZO[b,e][1,4]DIOXIN (TCDD) (Mixed isomers)		X				X											
TETRACHLORODIBENZOFURAN (TCDF)		X				X											

	Major Group				Detailed Group												
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
TETRACHLOROETHENE			X				X										
TETRAETHYL LEAD			X									X					
TETRAHYDROFURAN			X									X					
THALLIUM	X							X									
THALLIUM CHLORIDE				X						X							
THALLIUM COMPOUNDS	X							X									
THALLIUM(I) CARBONATE				X						X							
THALLIUM-204	X							X									
THALLIUM-208	X							X									
THORIUM-227	X							X									
THORIUM-228	X							X									
THORIUM-230	X							X									
THORIUM-231	X							X									
THORIUM-232	X							X									
THORIUM-234	X							X									
TIN	X							X									
TITANIUM	X							X									
TITANIUM DIOXIDE				X						X							
TOLUENE			X		X												
TOLUENE DIISOCYANATE (MIXED ISOMERS)		X									X						
TOTAL BENZOFLUORANTHENES		X															X
TOTAL EXTRACTABLE PETROLEUM HYDROCARBONS (TEPH)		X											X				
TOTAL PETROLEUM HYDROCARBON -DIESEL		X											X				
TOTAL PETROLEUM HYDROCARBON -GASOLINE		X											X				
TOTAL PETROLEUM HYDROCARBONS (TPH)		X											X				
TOTAL RECOVERABLE PETROLEUM HYDROCARBONS (TRPH)		X											X				
TOTAL TRIHALOMETHANES			X				X										
TOXAPHENE		X												X			
TRANS-1,2-DICHLOROETHENE			X				X										
trans-NONACHLOR		X												X			
TRIBUTYL PHOSPHATE		X									X						
TRIBUTYL(CHLORO)STANNANE				X									X				
TRIBUTYLSTANNANYLIUM				X									X				
TRIBUTYLSTANNYL BENZOATE				X									X				

	Major Group				Detailed Group													
Contaminant	Metal	SVOC	VOC	Other	BTEX	Dioxins and furans	Halogenated VOCs	Metals and metalloids	Other halogenated SVOCs	Other inorganics	Other nonhalogenated SVOCs	Other nonhalogenated VOCs	Other organics	Pesticides and herbicides	PCBs	PFOS/PFOA	PAHs
TRICHLORO(NITRO)METHANE		X												X			
TRICHLOROETHANE (MIXED ISOMERS)			X				X										
TRICHLOROETHENE			X				X										
TRICHLOROFLUOROMETHANE			X				X										
TRICHLOROPHENOL (MIXED ISOMERS)		X							X								
TRIFLURALIN		X												X			
TRIMETHYLBENZENE (MIXED ISOMERS)		X									X						
TRIPHENYL PHOSPHATE				X									X				
TRIS(2,3-DIBROMOPROPYL) PHOSPHATE		X							X								
TRIS(3-CHLOROPROPYL)PHOSPHATE		X							X								
TRITIUM				X						X							
TUNGSTEN	X							X									
URANIUM	X							X									
URANIUM, SOLUBLE SALTS	X							X									
URANIUM-233	X							X									
URANIUM-234	X							X									
URANIUM-234/235/238	X							X									
URANIUM-235	X							X									
URANIUM-238	X							X									
VANADIUM	X							X									
VANADIUM PENTOXIDE				X						X							
VANADIUM, METAL AND/OR ALLOY	X							X									
VERNOLATE		X												X			
VINYL ACETATE			X									X					
VX				X									X				
XYLENE (MIXED ISOMERS)			X		X												
ZEARALENONE				X									X				
ZINC	X							X									
ZIRCONIUM	X							X									