CHAPTER 6
Site Characterization

6.1 Introduction to Site Characterization

This chapter describes special considerations for residential lead sites, regardless of whether they are on the NPL or being addressed under removal authorities. During the site characterization phase of a remedial investigation or during a removal site evaluation, the sampling and analysis plan (SAP) developed during project scoping is implemented and field data are collected and analyzed to determine the nature and extent of threats to human health and the environment posed by a site (U.S. EPA 2018a, 1989b).

EPA has reviewed various sampling designs historically employed at lead-contaminated residential sites. EPA has assessed the ability of these sampling designs to meet the needs of site characterization, including providing data for a site-specific risk assessment, delineating the nature and spatial extent of contamination, and supporting the development of cleanup levels for removal and remedial actions.

While this Handbook was developed to promote consistent investigation and cleanup activities at Superfund lead-contaminated residential sites, flexibility is needed to best respond to local conditions and uncertainties.

The sampling approach for each site will be documented in the site-specific Quality Assurance Project Plan (QAPP), consistent with the EPA *Quality Assurance Project Plan Standard* (U.S. EPA 2023c). The plan documented in the QAPP should include, as part of the requirements of the Standard, the site-specific conceptual site model (CSM[64]), field sampling plan, and data quality objectives (DQOs).[65] Historical data are important when establishing a CSM. Development of an exposure CSM is a vital step because the exposure CSM establishes the lead-specific exposure pathways that will be quantified in the risk assessment. For example, for sites with a receptor accessing a non-residential site,[66] track-in of offsite soil or dust into the home should always be

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[64] A CSM is a comprehensive graphical and written summary of what is known or hypothesized about environmental contamination at a site and the relationships among key site characteristics that are pertinent to decision-making (see U.S. EPA 2020g, 1988c).

[65] Additional information on the DQO process can be found online at: http://www.epa.gov/quality/guidance-systematic-planning-using-data-quality-objectives-process-epa-qag-4.

[66] A residential recreator is an exposure scenario involving a receptor who both resides in a residential exposure unit (EU) and recreates at a different location (e.g., park, beach, or water body) EU that is part of the site. Their exposure includes both locations and is time-weighted according to U.S. EPA (2003c).

considered (that transport pathway may or may not be complete depending on site-specific conditions). The CSM can inform the collection of representative and high-quality data.

Additionally, Chapter 3 of this Handbook identifies opportunities to collaborate with other agencies and organizations to identify sources of lead exposure beyond the Superfund release. The sections in that chapter identify what the Superfund site team can do within CERCLA authority as well as when there are opportunities to collaborate and integrate with other programs. While it is recognized that collaborative partners will be able to better understand and implement required actions under their authorities, including those authorities delegated to states, tribes, and/or community members, broad descriptions of authorities and entities are included with footnotes and links to additional information (see Chapter 3 for more information).

6.2 Determining the Nature and Extent of Contamination

Historical information regarding facility operations and use is crucial for the design of SAPs to delineate contamination from a specific source. In addition to gathering data on the source of the release of contamination and historical operations documents, descriptive information should include both current and historical aerial imagery to identify areas where soil may have been moved, where fill or topsoil may have been placed, where soil was displaced because of natural processes, and historic use and development of all properties within the area to be characterized. EPA's Office of Technology Operations and Planning, Office of Environmental Information, Office of Mission Support High-End Scientific Computing, and Remote Sensing Information Gateway are sources of such aerial imagery. Sanborn fire insurance or other historical maps or photos, historic city directories, and historic news articles obtained through address or company searches may also be useful resources. Guidance is available from EPA concerning use of historical site data (NAS 2017, U.S. EPA 2001b, 2001c).

6.2.1 Background (Natural and Anthropogenic)

Delineating the extent of contamination generally distinguishes soil with *background* lead concentrations from soil contaminated by site-related activities. EPA guidance defines background as the following (U.S. EPA 2002a):

> Background refers to constituents or locations that are not influenced by the releases from a site, and is usually described as naturally occurring or anthropogenic (U.S. EPA 1995a, 1989b):

1) Anthropogenic – natural and human-made substances present in the environment as a result of human activities (not specifically related to the CERCLA release in question); and,

2) Naturally occurring – substances present in the environment in forms that have not been influenced by human activity (U.S. EPA 2002a).

Natural background concentrations of lead vary widely with local geology. Background reference areas should include natural and non-site-related anthropogenic sources (*e.g.*, historic automobile emissions, LBP), because these background concentrations estimate likely levels of lead unrelated to the CERCLA release and are indicative of recontamination levels post response action. Background samples should be collected from reference areas near the site that are not influenced by the site release, but that have the same basic characteristics (*e.g.*, zoning and land use, traffic density, population and building density, distance from traffic, housing age, lot size, building material, exterior paint, soil type). The OSC/RPM should collect background reference samples using the same methods used to collect onsite samples to support defensible site-versus-background comparisons.

Residential lead sites typically contain many small decision units (DUs), each with limited sampling density or data, which may pose a challenge to performing a statistical analysis as described in Superfund guidance. To address that challenge, RPMs and OSCs may use the Incremental Sampling Methodology (ISM) to assess background concentrations and compare them to concentrations of lead in onsite residential EUs where data have been collected using ISM. ISM is a structured composite sampling and processing protocol that reduces data variability and provides an unbiased, representative, and reproducible estimate of the mean concentration of a contaminant in a soil or sediment sample. This approach can demonstrably improve data quality and usability without increasing analytical costs, though it can require more up-front planning than discrete sampling. To compare background and onsite concentrations using ISM, all sampling should be done using the same ISM sample design and background areas should be of similar size to onsite areas. Further information on ISM can be found in Section 6.6, Appendix I, and Appendix J. Guidance on how to use ISM sampling can be found on the Interstate Technology and Regulatory Council (ITRC) website (ITRC 2020) and on the State of Hawaii Department of Health website (HDOH 2023).

Because OLEM programs generally do not clean up sites to concentrations below background concentrations and lead contamination is ubiquitous, characterization of background is important for risk management decisions (U.S. EPA 2002a). Background concentrations may be presented and discussed at the end of the risk characterization discussion of the risk assessment (*e.g.,* as an uncertainty or in an appendix), separately from site risks. Background concentrations are not subtracted from site samples. CERCLA releases are co-mingled with background contamination and PRGs are calculated based on the combined risk from the CERCLA release and background. If the risk-based PRG is less than the background concentrations, then the cleanup level should be based on background concentrations. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (U.S. EPA 2002b) and *Statistical Methods for Evaluating the Attainment of Cleanup Standards, Volume 3: Reference-based Standards for Soil and Solid Media* (U.S. EPA 1992) provide additional information on background concentrations in CERCLA response actions. Note that the approaches recommended in these two guidance documents differ substantially from the ProUCL Background Threshold Value (BTV) approach, which calculates an estimate of the upper tail of the background distribution (Technical Support Center for Monitoring and Site Characterization 2022). The ProUCL BTV approach is commonly used throughout EPA programs, including Superfund, to determine an upper bound estimate of the background concentrations, but it is <u>not the recommended approach</u> in Superfund background guidance. While the BTV approach assigns a certain confidence level to describing the upper tail of the background concentrations, the 2002 Background Guidance assigns a minimum acceptable confidence and power in comparing background concentrations to onsite concentrations (U.S. EPA 2002a).

EPA has discretion in how to determine background concentrations; OLEM's preferred approach at residential soil lead sites is described in the 2002 Background Guidance. As noted in the front material of the 2022 ProUCL technical manual (U.S. EPA 2022b), it is not Agency guidance or policy. It is a user's manual for statistical software. OLEM prefers to use the directly applicable Agency guidance, which in this case is the 2002 Background Guidance (U.S. EPA 2002a).[67] The approaches discussed in the 2002 Background Guidance provide a robust approach to determine whether a contaminated location has concentrations elevated above those at a background location, with appropriate estimates of the confidence and power levels. These methods directly support the use of background data at a Superfund site. The Background Threshold Module that is available in the ProUCL software provides a robust approach for calculating an estimate of the upper tail of a background data set, with an appropriate estimate of the confidence level. *Frequently Asked Questions About the Development and Use of Background Concentrations at Superfund Sites: Part One, General Concepts* (U.S. EPA 2018b) and *Role of Background in the CERCLA Cleanup Program* (U.S. EPA

[67] Note that to meet project-specific DQOs, a sufficient number of onsite samples will be needed to perform the recommended statistical hypothesis testing.

2002a) provide information and supplemental guidance on background. In cases where ARARs regarding cleanup to background levels apply to a CERCLA action, the response action generally should be carried out in the manner prescribed by the ARAR. When a law or regulation is determined to be an ARAR and it requires cleanup to background levels, then the ARAR will normally apply and be incorporated into the decision document (*e.g.*, Record of Decision [ROD]), unless the ARAR is waived.

Background data should meet site DQOs. In general, CERCLA response actions should use site-specific background levels (including both naturally occurring and anthropogenic sources). The *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (U.S. EPA 2002b) provides a decision tree to aid in determining whether existing background data are of sufficient quality to use for CERCLA decisions. The TRW Lead Committee provides information on state-specific soil lead geogenic background levels from the 2013 United States Geological Survey (USGS) study.[68] If the USGS background information does not meet site DQOs, then other background information or data should be sought or collected.[69]

Determining background concentrations for use in risk assessment or remedial decision-making can be challenging, particularly in urban areas or other areas with many sources of lead. The Office of Superfund Remediation and Technology Innovation (OSRTI) regional coordinator can facilitate assistance with support for study design, data analysis, and application of the data to Superfund decision-making. Statistical support can be obtained through the Site Characterization and Monitoring Technical Support Center.[70]

6.2.2 Delineation of Contaminated Areas

Statistical approaches for delineating contaminated areas are often useful. OSRTI technical experts are available to consult with RPMs and OSCs, including the Technology Integration and Information Branch, the Technical Review Workgroup for Lead,[71] and the Environmental Response Team. The collection of samples from all potentially contaminated media is critical to accurately determine the nature and extent of contamination and ensure that the sampling is adequate and complete. The CSM should address whether or not aerial deposition of the lead contamination is a probability or whether the contamination migrated in other ways (*e.g.*, use of lead-contaminated material as fill material or for driveways). If the contamination was

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[68] https://www.epa.gov/superfund/lead-superfund-sites-united-states-geological-survey-usgs-background-soil-lead-survey.
[69] For example, https://www.epa.gov/risk/regional-urban-background-study.
[70] https://www.epa.gov/land-research/site-characterization-and-monitoring-technical-support-center-scmtsc
[71] https://www.epa.gov/superfund/lead-superfund-sites-technical-assistance.

released by aerial deposition, there is a potential for contamination inside homes. Fence lines, property lines, and landscaping should never be used to delineate the extent of contamination. The effectiveness of geostatistical analyses for delineating the spatial extent of contaminant zones has been widely demonstrated (Goovaerts 1997, Englund and Heravi 1994, Flatman and Yfantis 1984, Journel 1984, Gilbert and Simpson 1983). See U.S. EPA (1995c) for more information.

6.3 Sampling Environmental Media for Risk Assessment

The risk assessment sampling approach should be informed by the sampling objectives in the DQO and the exposure CSM (described in Section 6.1). The exposure and other information in the CSM should be updated throughout the investigation and cleanup process as data are collected and evaluated. EPA recommends that sampling at lead-contaminated residential sites focus on an individual residential property as the primary EU of concern[72] while recognizing that exposure does not end at the property line (U.S. EPA 1998), especially in light of potential access, cleanup, and eventual property transfer considerations (see Sections 6.5 and 6.9 for additional information). This information is beneficial to the risk manager when considering appropriate risk reduction strategies for those areas.

The overarching goals of sampling are the following:

- Collect data and information to support current or future risk-based decisions.
  - Considerations include identifying EUs or DUs (see Section 6.5 for more information) as well as media and receptors for complete exposure pathways (current and potential future).
  - Determine mean lead concentrations in media to generate exposure point concentrations (EPCs) for likely exposures for receptors (U.S. EPA 2007a): appropriate sample depth for soil media that represents the site-specific exposure such as, but not limited to, direct contact for incidental ingestion and gardening, disturbed or undisturbed sampling of surface water from an appropriate depth depending on exposure, and sieving of solid media (soil should be sieved to achieve a 150-µm particle size fraction because it is most likely to adhere to hands for incidental ingestion exposures; see Section 6.11 [U.S. EPA 2016]).
- Collect data and information to support nature and extent characterization.
  - Determine the geographic extent of site-attributable contamination to support potential cleanup planning.

[72] The primary EU of concern could include several sampling DUs.

- Identify sources of contamination and the fate and transport of the contaminants through the study area.

With input from the site team, RPMs/OSCs should design sampling to meet the data needs and DQOs to support defensible site decisions (U.S. EPA 2006). An important criterion for defensible data is demonstrated reproducibility. The sampling designs discussed in this section support decision-making during all phases of the project to avoid repeat sampling and mobilizations. Representative site-specific data are used to calculate EPCs for risk assessment, develop remedial action objectives (RAOs), and determine cleanup levels under CERCLA.

The DQO process documented in the SAP QAPP provides a structured approach to problem formulation to guide collection of environmental data that are of sufficient quality and quantity and relevant to support the site investigation, risk assessment, and risk management decisions (U.S. EPA 2006). Systematic planning provides a framework for documenting site information: sample number, sample size, sample locations and media type, bioavailability analysis, laboratory analyses, temporal and meteorological factors, sieving, sampling depth, and sampling costs (see the *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A* [U.S. EPA 1989b] and the *Guidance for Sample Collection for In Vitro Bioaccessibility Assay for Arsenic and Lead in Soil and Applications of Relative Bioavailability Data in Human Health Risk Assessment* [U.S. EPA 2020c]). See Section 6.13 for information on how to sample for bioavailability and apply those data to the HHRA.

A site-specific SAP QAPP includes a field sampling plan to ensure that the samples collected meet the DQOs for the site and therefore will support site decisions. This includes making sure that the number and type of samples collected are adequate to characterize the concentration of the contaminant with sufficient statistical power, and that the area sampled spatially represents the anticipated variability of concentration within the exposure area. Samples represent the media that receptors contact (*e.g.*, soil depth likely to be contacted and subsequently incidentally ingested). A risk assessor should be involved in developing the SAP QAPP to ensure that the field sampling plan and subsequent analytical results will provide defensible and fit-for-purpose data for the risk assessment.

Collecting reproducible data of known and documented quality is necessary to support risk management decisions. The type and quantity of sampling needed at a given location will be site-specific and based on factors such as the sampling objectives and the current understanding of the CSM, discussed in further detail in Table 6-1.

Exposure information needed to quantify risks at sites includes media-specific concentration data (*e.g.*, residential soil lead concentration) and may include site-specific exposure data. Site-specific environmental lead concentration data from the media of interest (*e.g.*, air, water, soil, or sediment) should be sampled to determine the concentration of lead at a scale relevant to the receptor's EU. If soil or sediment are media of interest, site-specific bioavailability data should generally also be collected (U.S. EPA 2020c).

For most exposure factors used in risk calculations (*e.g.*, age, body weight, breathing rate, or soil ingestion rate), the Superfund program has standard default parameters that are built into the EPA IEUBK Lead Model.[73] Information for some site-specific exposures (*e.g.*, the number of days per week that young children visit a recreational area away from their home) may also be needed. Consultation with a risk assessor ensures that the sampling plan is designed to collect the information needed to support the site-specific baseline risk assessment.

Typical reasons for sampling various media at residential properties are provided in Table 6-1. The collection of other types of media (*e.g.*, residential water, soil, or sediment lead concentrations at a nearby recreation area) may help to determine overall risk as well. The site team should consider which of these apply to their site, since not all are necessarily applicable.

Table 6-1. Reasons for Sampling Environmental Media at Residential Properties

Sample Location	Rationale for Sample Collection
Residential property soil	Surface soil is a direct incidental exposure pathway for residents. Soil samples should be collected and analyzed to estimate average lead concentrations as well as site-specific *in vitro* bioaccessibility (IVBA) (U.S. EPA 2020c). Depending on the size and uses of the property, it may be sampled as an entire yard, or it may be divided into smaller DUs. Residential soil may also be part of an indirect exposure pathway via house dust exposure. Biased samples should never be used to estimate average concentrations. DUs should reflect potential exposure patterns, play areas, gardens, etc. and EUs should be designed such that the receptor has an equal probability of being exposed anywhere within the EU.
Soil in play areas	Soil in play areas is part of a direct exposure pathway to children of all ages, but especially to younger children. Samples should be collected both inside and outside sandboxes, play areas, or similar structures. Depending on the property size and layout, play areas should be separate DUs because they are likely contacted frequently. Soil samples should be collected and analyzed to estimate lead concentrations as well as site-specific IVBA.

[73] See https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals.

Table 6-1. Reasons for Sampling Environmental Media at Residential Properties

Sample Location	Rationale for Sample Collection
Gravel driveways	Fine-grained driveway material may be part of a direct exposure pathway and an indirect pathway when contamination is tracked into the home and contaminates indoor dust (both because the gravel may be contaminated with lead and because the soil below the gravel driveway may be contaminated and gravel is not an effective barrier). Samples may be collected from the driveway and from beneath the gravel layer to estimate lead concentrations as well as site-specific IVBA.
Rooftops, drip zones, and soil areas below roof gutter downspouts	Rooftops, downspouts, and drip zones may concentrate lead from aerial deposition or LBP. Drip zone areas (commonly approximately 4-6 feet from the base of the structure) on structures with LBP may also contain LBP residue. Characterizing the lead concentration in the drip zone may be important at some sites, but the drip zone is not representative of the overall exposure for a residential lot. Site teams may choose to evaluate drip zones as a separate DU or as part of the yard DU, depending on the DQO.
Garden soil	Garden soil may be part of a direct exposure pathway to persons who actively maintain a garden (U.S. EPA 2013). Soil samples should be collected and analyzed to estimate lead concentrations as well as site-specific IVBA. The TRW Lead Committee has developed supplemental guidance for garden areas[74].
Interior lead dust	Lead in household dust may represent an important exposure pathway, but it may also include LBP or other sources not addressed under CERCLA authority. Dust exhibits temporal variability relative to soil and presents significant logistical challenges. If soil contamination is controlled, then it will no longer contaminate house dust (von Lindern et al. 2003). Dust samples may be collected and analyzed to estimate lead concentrations as well as site-specific IVBA. Because lead-contaminated interior dust can be derived from multiple sources (U.S. EPA 2008), please refer to CERCLA guidance/limitations on sampling and response actions indoors (U.S. EPA 2009, 1993). The IEUBK model includes a module that predicts house dust lead concentration from outdoor soil concentration, so interior dust sampling is generally not needed to assess risk for residential areas. Consultation with the TRW Lead Committee is recommended when designing sampling plans to collect indoor dust lead samples.
Lead-based paint (LBP)	Deteriorating LBP may contribute lead to household dust or soil. If elevated concentrations of lead are found in interior dust, then samples of interior paint should be collected and analyzed to estimate lead concentrations. Deteriorating LBP or a history of exterior LBP may contribute to the contamination of yard soil in the dripline and recontamination of remediated properties. Samples of exterior LBP should be collected and analyzed to estimate lead concentrations. A Field-Portable X-Ray Fluorescence (FP-XRF) spectrometer to measure for interior and exterior LBP is recommended for paint sampling. Reference CERCLA guidance/limitations on sampling indoors (U.S. EPA 2009, 1993).

[74] https://www.epa.gov/superfund/lead-superfund-sites-guidance#gardening.

Table 6-1. Reasons for Sampling Environmental Media at Residential Properties

Sample Location	Rationale for Sample Collection
Residential drinking water and public water supply	Groundwater and surface water containing elevated lead concentrations provide an exposure route for ingestion. Some residences located within the site may use local groundwater or nearby surface water as a source of drinking, cooking, and/or irrigation water. Residential water lead information may be derived from the municipal water supply (*e.g.*, SDWA reporting data) or by collecting samples of residential tap water. Residential tap water may be collected from standing water in the pipes (first-run sample) and water discharged after the home plumbing system has been flushed (flushed sample); both kinds of samples should be collected and analyzed to estimate lead concentrations. Consideration should be given to the potential source of lead contamination in the drinking water (either site-specific wells, residential plumbing, or distribution service lines, or contamination from the municipality).
Crawl spaces and attics	Crawl spaces and attics should be sampled if they are accessible to, and regularly used by, children and/or pets. At some sites (*e.g.*, Bunker Hill Superfund Site, Idaho), this has been found to be a significant exposure pathway (IDHW 2000, TerraGraphics 2000). Pets can transport fine dust containing elevated lead levels into the residence (*e.g.*, where a pet may sleep on the child's bed at night) from crawl spaces (TerraGraphics 2000). Information on concentrations of lead in attics or crawl spaces of the residence may be used to document the need to preclude access or take other response actions to reduce exposure. Consultation with EPA's TRW Lead Committee is recommended when designing sampling plans to collect indoor dust lead (attic) samples.
Other areas within the site	Because exposure is likely to occur throughout the site, other properties should also be sampled, including residences of extended family, day care facilities, schools, and parks within the site. These exposures could be assessed quantitatively in the risk assessment using the Intermittent Exposure Guidance (U.S. EPA 2003c) or be remediated by applying residential cleanup levels to other site-related locations frequented by residents.
Air	Outdoor air samples may be collected to replace the default air lead concentration in the IEUBK model. Additionally, consideration can be given to whether the site is near a lead non-attainment zone.[75] PM10 data monitoring data (from at least 4 quarters or an annual average) may be used in the IEUBK model. The IEUBK model converts outdoor air lead concentrations to indoor air lead concentrations.

6.4 Residential Soil Sampling

6.4.1 Sampling Consent for Access

Prior to conducting any sampling or CERCLA response activities at a residential property, access must be obtained from the property owner, either on consent or through an enforcement instrument; access obtained from tenants or renters is not sufficient. RPMs/OSCs should coordinate closely with the ORC to obtain access for sampling. Coordination with ORC is

[75] Lead non-attainment zone: https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=8fbf9bde204944eeb422eb3ae9fde765.

important as renters' rights vary by locality and while generally not sufficient for access, having renters' consent does help if other enforcement instruments, such as warrants, might be considered for access. It is essential to begin obtaining access as early as possible in the response process to avoid potentially lengthy delays. Access consent can be obtained through door-to-door interactions, community meetings, and/or direct mailings. It may be more cost-effective to use direct mailings followed by door-to-door outreach in areas with poor responses. In areas occupied by renters, this may not be sufficient. Examples of access consent forms are presented in Appendix F. If possible, access for remediation should be obtained at the same time as access for sampling is sought. Examples of combined sampling/remediation access consent forms are included in Appendix F. Combining sampling and cleanup access will avoid delays. Where applicable, access should be obtained for any interior dust sampling and/or cleaning that may be performed at the residence. Additionally, the OSC/RPM can provide questionnaires requesting information on indoor lead sources. These could be provided in combination with a property access request. For an example of a sample questionnaire, see Appendix O and Section 6.7.1.

6.5 Sampling Units, Exposure Units, and Decision Units

The primary objective of sampling residential soil at lead sites is to accurately determine the representative soil lead concentrations for decision-making. EUs, sampling units (SUs), and DUs are terms used when discussing sampling areas of solid media. For the purposes of this Handbook, these terms are defined as:

- Exposure unit (EU): The EU is generally determined by the receptor and exposure scenario in the geographic area in which individuals are randomly exposed to a contaminated medium for some relevant exposure duration (*i.e.*, receptors have an equal probability of being anywhere in an EU over the exposure duration). Environmental sampling provides information about the contamination within and around an EU. Multiple EUs may be defined at a site based on the population(s) of interest, exposure medium, and nature of contact with that medium. For example, residential exposures for children may involve exposures via incidental soil ingestion in a yard with a drip zone impacted by LBP (the yard is the EU comprising separate SUs and/or DUs for the yard and drip zone) (U.S. EPA 2001b, 2001c). An EU can contain one or more SUs or DUs.

- Sampling unit (SU): The SU is defined as an area of soil selected for sampling that will be represented by the sample data collected within it. The SU is generally determined by the known or anticipated concentration of contaminants over a geographic area. It is defined as the area of soil selected for sampling to derive an estimate of the mean lead concentration for that area. EUs and DUs may be composed of one or more SUs. The purpose of having smaller SUs is to gather information about contaminant patterns or trends within specific areas of EUs or DUs to refine the location of contamination for more precise removal of the contamination. SUs are specific to the study objectives and should be determined by the site team during DQO and SAP QAPP development. An example of an SU is a drip zone around a home with suspected LBP on the exterior of the home.

- Decision unit (DU): The DU is defined by the risk management team. The DU is the smallest geographic area of soil that will be subject to a risk-based decision. A DU may consist of one or more SUs and be the same as, or smaller than, an EU. A DU can contain one or more SUs.

Sampling at residential properties that are one-tenth of an acre (a typical urban lot) would be approached differently than a greater-than-10-acre property (which may be encountered in a rural setting). Portions of some large properties may not be utilized regularly by the residents (*e.g.*, forested land). Sampling should be focused where residents are most likely to come in contact with soil, such as gardens and play areas. Discussing land use with residents prior to sampling is essential to support a sampling plan based on known or likely exposure and may differ at individual properties. This is particularly important in cases where the entire property cannot be sampled. Consultation with risk assessors early in the sampling design process is recommended to develop a site-specific strategy for sampling areas.

6.6 Soil Sampling Methods

Table 6-2 highlights three soil sampling methods (incremental composite sampling [ICS], composite sampling, and discrete sampling) that can be used to provide an unbiased estimate of the mean concentration and may be appropriate for collecting soil lead concentration data for use in the risk assessment and/or characterizing nature and extent. In addition to sampling and analysis approaches that rely on destructive analytical techniques, x-ray fluorescence (XRF) analysis may be used at sites depending on the DQOs for sampling and analysis. The heterogeneous composition of soil combined with complex contaminant distribution patterns can result in highly variable concentrations over both short and long distances at a site. Because ICS approaches are better at incorporating the variability of soil concentrations with a smaller number of chemical analyses, this sampling design is generally preferred over other sampling approaches (ITRC 2020, 2012, Brewer et al. 2016a, 2016b).[76] The appropriate and optimal sampling design will depend on site-specific conditions (*e.g.*, SU area), study objectives, data requirements for the risk assessment (*e.g.*, number of replicates), resources available, the CSM, and DQOs (see Appendices J and K for additional information).[77]

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[76] https://www.clu-in.org/conf/itrc/ISM_051514/ISM-hotspot-FAQ-Final.docx.
[77] https://health.hawaii.gov/heer/guidance/specific-topics/decision-unit-and-multi-increment-sampling-methods/.

Table 6-2. Typical Soil Sample Methods Used at Lead-Contaminated Sites

Incremental composite sampling (ICS)	ICS, also known as multi-increment sampling, can provide an unbiased and reproducible estimate of the mean concentration within an SU. An ICS is assembled from a large number (*e.g.*, 30-100) of samples (*i.e.*, increments) of equivalent size/mass collected from simple random or systematic random locations across the SU. The process typically yields a large sample mass (*e.g.*, 1-3 kilograms). Typically, incremental samples are carefully processed and subsampled in the laboratory to increase the likelihood that the analytical result is "representative" of the mean concentration within the SU. The large number of increments, large sample mass, and carefully planned processing/subsampling procedures work together to reduce both small- and large-scale variability and produce a defensible estimate of the mean contaminant concentration within the SU.
Composite sampling	A typical composite sample is assembled from a small number (*e.g.*, fewer than 10) of discrete samples that are combined in the field. The discrete component samples may be collected in a clustered pattern (*e.g.*, a 5-point composite) or from simple random or systematic locations across the SU. Careful consideration of the mass of each discrete component sample is necessary to ensure that an unbiased and "representative" composite sample is achieved of sufficient mass to achieve the analytical goals. Composite samples can reduce small-scale variability by physically combining samples from a small area. Composite samples may be appropriate for small areas such as drip zones and play areas that are too small to support triplicate ICS. Composite samples are typically combined and homogenized in the field and a subsample of the composite is placed into sample containers specified by the analytical method. The sample volume and additional sample processing can vary based on site-specific DQOs.
Discrete sampling	Discrete samples can be collected from biased or random sample locations. The samples are collected from a single location and placed into sample containers specified by the analytical method. The sample volume and additional sample processing can vary based on site-specific DQOs. Individual discrete samples tend to exhibit highly variable concentrations at both small and large spatial scales and generally require a large sample size to achieve a "representative" sample for risk assessment. Biased discrete samples are not recommended because they do not efficiently or reproducibly estimate the mean concentration of lead in a DU. Discrete samples may be used to characterize the concentration of contaminants in material known to be homogeneous (*e.g.*, a waste rock pile at a mining site).
XRF analysis	Sampling information from XRF analysis may be used to support characterization of nature and extent of contamination. Because of their speed, low cost, and ease of use, FP-XRF instruments are often used for screening to quantify metal concentrations in solid media at hazardous waste sites. XRF is a non-destructive screening-level analytical technique used to determine the elemental composition of materials. XRF analyzers determine the chemistry of a sample by measuring the fluorescent (or secondary) x-rays emitted from a sample when it is excited by a primary x-ray source. Each of the elements present in a sample produces a set of fluorescent x-rays having a characteristic wavelength spectrum ("a fingerprint") that is unique for that specific element, allowing for qualitative and semi-quantitative analysis of material composition. U.S. EPA (2007b) notes that XRF is a screening method to be used with confirmatory analysis using other

Table 6-2. Typical Soil Sample Methods Used at Lead-Contaminated Sites

	techniques (*e.g.*, flame atomic absorption [FLAA] spectrometry, graphite furnace atomic absorption [GFAA] spectrometry, inductively coupled plasma-atomic emission spectrometry [ICP-AES], or ICP-mass spectrometry [ICP-MS]). Final remedial decisions around the decision point should be confirmed with definitive information derived from confirmatory analytical techniques (including IVBA). See the *Superfund X-Ray Fluorescence XRF Field Operations Guide* (U.S. EPA 2017b) for more information. Notes: 1. XRF measurement does not inform site-specific bioavailability. 2. XRF samples are expected to be *ex situ* and sieved to the relevant particle size for risk assessment.

Sampling designs should include collection of a sufficient number of samples to adequately control Type I and Type II statistical error (*i.e.,* false positive and false negative error rates) to achieve reproducible and defensible data required for decision-making (U.S. EPA 2006).[78] Collection of biased discrete samples from known or supsected areas of contamination may be appropriate for screening on a presence/absence basis; however, biased discrete samples should not be used to calculate the mean contaminant concentration for an SU for risk assessment, limiting the use of biased sampling for risk assessment or cleanup decisions. Biased data are usually of unknown quality and may lead to an unreliable estimate of contamination.

Composite samples combine discrete, mass-defined samples from multiple locations to arrive at an estimate of the mean contaminant concentration with relatively fewer samples and, therefore, lower analytical costs than discrete sampling (that are often combined mathematically) (U.S. EPA 1995d). For example, a common approach for small SUs (*e.g.*, <100 square feet) is to collect five equivalent mass samples in a geometric pattern (*e.g.*, five points arranged in a cross, with four of them forming a square or rectangle and a fifth at its center), which are then combined, homogenized, and submitted as a single composite sample for analysis. Composite samples with fewer than 10 samples generally cannot be used to approximate spatial variance of lead concentration within the SU from which the composite sample was collected and are not recommended (U.S. EPA 1995d). An adequate number of composite samples must still be collected in order to obtain an estimate of the population variance and control for large scale heterogeneity (U.S. EPA 1995d). In general, if incremental or other composite-type sampling is determined to be the most effective sampling method at a site, triplicate sampling within an SU can be used in which the entire pattern of increments/

[78] ProUCL and related guidance is available to inform the number of samples necessary to support decision-making.

composites is performed three times to provide a measure of reproducibility of the estimated mean and the global variance.[79]

6.7 Lead-Based Paint (LBP) and Interior Dust Sampling

Deteriorating LBP may contribute lead to household dust. If elevated concentrations of lead are found in interior dust in the absence of outdoor soil sources, the source of lead may be interior LBP. Lead in household dust may be a significant contributor to elevated blood lead in younger children. Lead-contaminated interior dust can be derived from multiple sources; dust mat samples (in concert with speciation of lead) can be used to identify lead sources. Indoor dust samples may be collected and analyzed to estimate its potential contribution to lead exposure.[80] Wipe samples measure lead loading (mass of lead per area), not concentrations (mass of lead per mass of dust). As such, wipe sample results are not appropriate for use in the IEUBK model (because the IEUBK model requires concentration data). Guidance on LBP and dust sampling is available from HUD (2012). More information on interior dust sampling for use in lead risk assessment at Superfund sites is available (see U.S. EPA 2008).

6.7.1 Collaboration to Identify and Address Lead-based Paint Hazards[81]

Collaboration with other EPA programs, other federal agencies, states, tribes and/or local governments may be required to ensure that exposures to lead from lead paint are identified and addressed. There may be situations that warrant additional collaboration, such as where the site team suspects that an LBP hazard could pose an exposure risk to residents within the boundaries of the Superfund site, in addition to the CERCLA release. Lines of evidence suggesting an LBP hazard that would require additional collaboration may include screening or analytical data, available geospatial census level data, construction date (pre-1978), and/or condition of the structure. When evidence at a site suggests that an LBP hazard exists, it is recommended that the RPM, OSC, and/or CIC (or other identified convener) coordinate with the regional and/or state, tribal, or territory LBP program.

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[79] Note that triplicate samples for a DU or EU at a relatively small residence may constrain the ability to make robust statistical comparisons to background due to limited statistical power.

[80] CERCLA authority to address these sources may be limited; refer to Chapter 2 for additional information on CERCLA limitations.

[81] Under Toxic Substances Control Act (TSCA) Section 401 (15 U.S.C. 2681), LBP hazards are defined as conditions of LBP and lead-contaminated dust and soil that would result in adverse human health effects. As defined in TSCA section 401 (15 U.S.C. 2681(9)), LBP means paint or other surface coatings that contain lead in excess of 1.0 milligrams per centimeter squared or 0.5 percent by weight or (1) in the case of paint or other surface coatings on target housing, such lower level as may be established by HUD, as defined in 42 U.S.C. 4822(c), or (2) in the case of any other paint or surface coatings, such other level as may be established by EPA.

6.8 Residential Drinking Water and Public Water Supply

Groundwater and surface water may contain elevated lead concentrations impacting drinking water used for consumption. Some residences located within the site may use local groundwater or nearby surface water as a source of drinking, cooking, and/or irrigation water. As noted in Section 6.3, Table 6-1, consideration should be given to the potential source of lead contamination in the drinking water (either site-specific wells, residential or distribution water lines, or contamination from the municipality).

If lead is present in drinking water due to the site release, Superfund has authority to address the issue and the EPA regional Drinking Water program may be informed for situational awareness. If it is determined that lead is present in drinking water because of lead plumbing or fixtures, then the Superfund site team (or other identified convener) should inform the regional Drinking Water program to coordinate activities to reduce exposure to lead (because these sources are generally excluded from Superfund authority). If it is determined that a drinking water supply is impacted by corrosion of lead plumbing, the Superfund site team (or other identified convener) can also determine if federal partnerships have already been established that would help address the problem, such as EPA's free Water Technical Assistance (Water TA) services and programs,[82] and EPA's Urban Waters program.[83]

6.8.1 Collaboration to Identify and Reduce Exposure to Lead in Drinking Water

If lead is found in groundwater as part of the release and/or due to migration from site-related sources of lead in soil to groundwater, the Superfund site team, after briefing the appropriate Section and/or Branch management (as needed), should inform the EPA regional Drinking Water program as well as the impacted public water system for situational awareness.[84] The lead in groundwater and drinking water (if impacted) would be addressed under Superfund authority if it is determined to be related to a site release.

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[82] https://www.epa.gov/water-infrastructure/water-technical-assistance-waterta

[83] Urban Waters Federal Partnership: The EPA urban waters regional contacts can be found by navigating to each individual partnership page: https://www.epa.gov/urbanwaterspartners. Urban Waters program fact sheet: https://www.epa.gov/sites/production/files/2015-09/documents/uwfp_factsheet-final.pdf.

[84] In accordance with the 1996 amendment to the SDWA, every state exercising primacy enforcement responsibility for public water systems must assess its sources of drinking water to identify significant potential sources of contamination and to determine how susceptible the sources are to these threats. While there is no federal requirement to update these assessments, some states do require updates. Any impact to groundwater due to migration from site-related sources of lead in soil should be shared with the regional drinking water program so that the information can be communicated to the states. For more information, see: https://www.epa.gov/sites/production/files/2015-04/documents/epa816f04030.pdf.

If the public water supply and/or tap water data indicate that lead is present because of corrosion and/or leaching of lead from pipes or fixtures within the boundaries of the Superfund Site, the Superfund site team should collaborate with, and direct the issue to, the regional Drinking Water program since Superfund does not have the authority to address this source of lead.

The following bullets describe the recommended steps for identification and coordination when lead is or may be in drinking water:

- If private drinking water wells are in the footprint of, or near, the impacted groundwater, Superfund would conduct an investigation that may include sampling the private wells to determine if lead is present in the drinking water and related to the site release (Section 6.3). Additionally, the Superfund site team, including the site human health risk assessor, can coordinate with ATSDR to ensure that the public is receiving appropriate outreach and educational materials.
- If the public water system[85] is drawing groundwater or surface water from within the boundaries and/or vicinity of the Superfund site, the site team should take steps to determine if the drinking water supply is impacted by the site release.
- The Superfund site team may review publicly available information reported by the public water system, if this information is readily available, but it is recommended that the Superfund site team connect with the EPA regional Drinking Water program through the Drinking Water Branch Chief, especially if data indicate that the public water supply may be impacted by the site release. The primacy agency (*i.e.*, state, tribal government, or EPA region) would work with the public water system to pursue data collection to determine if influent and effluent treatment system data indicate that lead from the Superfund release is impacting the public water supply.
- There may be instances[86] where the RPM or OSC (or contractor) may collect a subset of residential tap water data such as for use as an input to the IEUBK[87] model. The site human health risk assessor should be consulted regarding tap water sampling for use in the IEUBK model. The RPM should also consult with the regional Drinking Water program, which can provide a reference to a current list of approved sampling methods

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[85] A public water system may be publicly or privately owned. EPA has defined three types of public water systems according to the number of people they serve, the source of their water, and whether they serve the same customers year-round or on an occasional basis. For more information, see https://www.epa.gov/dwreginfo/information-about-public-water-systems.

[86] These decisions will be made based on site-specific information, such as past industrial practices or processes that may result in mobilizing lead in soil.

[87] Current versions of the IEUBK model and relevant guides and guidance can be found at: https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals.

for drinking water compliance under the Lead and Copper Rule (LCR; 40 CFR 141.86(b)).[88]

- If residential tap water data show that lead is present in drinking water, then the Superfund site team should inform the EPA regional Drinking Water program and share information such as the tap water sampling methods and protocol as well as analytical data.

- The EPA regional Drinking Water program contact, the state contact, or the local public water system may be able to inform the Superfund site team of the presence or absence of lead service lines, if that information is known, and may assist in evaluating public water supply data to determine if there have been lead action level exceedances and health-based violations of the effective LCR or future revisions of this rule.

- The Superfund site team may also want to work with the regional geographic information system (GIS) team to determine if geospatial data layers exist with respect to public lead indices based on old housing (including the Environmental Justice Screening and Mapping Tool [EJSCREEN] and other EPA tools).

- The Water Infrastructure Improvements for the Nation (WIIN) Act that was enacted on December 16, 2016, explains the notification and coordination requirements that EPA must follow when EPA develops or receives data (other than from a primacy agency or a public water system) indicating that household water testing results exceed the lead action level. *The Strategic Plan for Targeted Outreach to Populations Affected by the Lead WIIN Act* outlines the statutory requirements and process for distributing sampling data to the public water system or state, and notification requirements. It is important that if the Superfund site team is sampling from residential taps and analytical data indicate an action level exceedance, the Superfund site team is prepared to implement the Strategic Plan. The first step is to immediately notify the Drinking Water program and provide the associated data so the manager responsible for the regional Drinking Water program can orchestrate the required data sharing and notification within a timeframe consistent with the Strategic plan[89] and per the requirements of the WIIN Act (U.S. EPA 2017c).

6.9 Sampling for Exposures at Secondary Areas and Community-Wide Exposures

Exposure does not end at the property line (Laidlaw et al. 2014, Zahran et al. 2013a, Laidlaw and Filippelli 2008, Sheldrake and Stifelman 2003). Lead-contaminated soil-dust moves at various scales via wind, vehicular tracking, or transport on clothes, shoes, tools, equipment, or pets (Zahran et al. 2013b). It is important to consider whether there are other areas of lead

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[88] See 40 CFR 141.86(b) for guidance on collecting tap water samples for lead: https://www.law.cornell.edu/cfr/text/40/141.86.

[89] See Figure 1 in the *Strategic Plan for Targeted Outreach to Populations Affected by Lead Water Infrastructure Improvements for the Nation (WIIN) Act*. Accessing the file at https://www.epa.gov/sites/default/files/2017-07/documents/wiin_strategic_plan_july_18_finalv5.pdf provides an interactive version of the figure.

contamination that represent an additional, distinct exposure area (*e.g.*, neighboring parks or play areas; schools and daycare locations; or areas where trespassing may occur). Because releases and possible corresponding exposures can extend beyond property lines, and both children and soil-dust are mobile, properties in the vicinity of a residence may be considered as part of the exposure area (Zahran et al. 2013a, 2013b, Sheldrake and Stifelman 2003). In such cases, these areas should be evaluated on a case-by-case basis to determine the extent of the exposure duration and frequency; sampling may also be recommended to determine how concentrations at these locations differ from the residential scenario. Sampling at these locations/properties should generally be consistent with the DQOs for residential properties. EPA's *Assessing Intermittent or Variable Exposures at Lead Sites* guidance document presents a methodology for the assessment of lead risks when exposures may occur at secondary locations (U.S. EPA 2003c).

6.10 Soil Sampling Depth

Sampling depth depends upon the CSM and the exposure scenario(s) for the site, but in most instances, the recommended soil sampling depth is the top 0-1 inches (0-2.5 centimeters [cm]) for direct contact with surface soil, where typical exposures for children are most likely to occur. However, there may be more than one exposure scenario for the site. For example, one exposure scenario at a site may be children playing at a residential property with exposure to contaminated surface soil; the same site might also include a deeper horizon for a sandbox (*e.g.*, 0-6 inches) or garden area (*e.g.*, 0-12 inches). The sampling depth should match the exposure pathways and contaminant transport routes of concern.

Sampling depth also varies depending upon site-specific conditions. The *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual, Part A* (U.S. EPA 1989b) states that the assessment of surface exposures will be more certain if samples are collected from the shallowest depth that can be practically obtained to avoid dilution if the transport mechanism is aerial deposition or fugitive dust. Keeping in mind the broader considerations mentioned above, to assess risk from current exposure to lead-contaminated surface soil, EPA generally recommends the collection of the top inch (0-1 inches or 0-2.5 cm) of the soil layer for determining direct contact exposure to surface soil (U.S. EPA 1996b). In some cases, grass, organic litter, sod, wood chips, or sand will be encountered and soil below the cover material should be collected (U.S. EPA 1996b). If aerial deposition is the dominant source of contamination, the soil is undisturbed, and surface soil concentrations are below screening levels, it may not be necessary to collect samples at depths greater than (>) 1 inch.

If contamination is found at depths below 1 inch, or 2.5 cm, then the risk assessment for the current exposure scenario should consider the likelihood of whether children (or other receptors) may be exposed to soil at that depth and select the sampling depth accordingly. Samples collected at depths >1 inch below ground surface (bgs; *i.e.*, subsurface) may also be appropriate for risk management purposes, such as future use scenarios (*e.g.*, play areas, gardening, construction or utility work, yard maintenance). To assess risks from exposure to contaminated subsurface soil, samples should be collected from the depth interval that is consistent with the applicable exposure scenario as determined by the site team based on site-specific information (*e.g.*, several depth intervals down to 24 inches bgs; 0-1, 1-6, 6-12, 12-18, and 18-24 inches). The EPC for each exposure scenario should be estimated with data from the depth interval(s) relevant to each scenario. Regions or states may have specific guidance on sampling depths.

Soil samples below 1 inch may also be useful for determining where ICs may be needed; response actions may warrant ICs or post-removal site controls if subsurface contamination remains following a response action. Please refer to Chapter 10 for additional information on ICs.

6.11 Sample Preparation (Sieving)

Samples should represent current or potential future exposure to young children. Children inadvertently ingest lead from fine particles of contaminated soil and dust that adhere to their hands, toys, and other objects they put in their mouths. Additionally, smaller particles migrate more easily into the home. Therefore, sieving of soil samples is recommended to better represent the soil-dust fraction that is incidentally ingested by children. Accordingly, lead concentrations in soil samples should be measured in the fine particle fraction of <150 µm (#100 sieve), or at a particle size fraction of <250 µm (#60 sieve) for sediment samples.[90] In rare cases (such as where bullet fragments are present), it may be that the coarse fraction (*i.e.,* the fraction that does not pass through the selected sieve) or the total unsieved sample (*i.e.*, the fraction that is <2 mm) must also be analyzed for at least a portion of samples at sites where the CSM suggests that significant lead may be present in the coarser fraction (*e.g.*, shooting ranges[91], artisanal lead recovery/reuse operations) because these larger lead particles may weather over time to increase the concentration of lead in the finer fraction. Consultation with

[90] OLEM Directive 9200.1 128 (U.S. EPA 2016) *Recommendations for Sieving Soil and Dust Samples at Lead Sites for Assessment of Incidental Ingestion.*
[91] See U.S. EPA (2003e)

a risk assessor is recommended when the lead concentration is higher in the <2 mm fraction than in the finer fractions of a sample.

6.12 Holding Times

EPA evaluated sample holding times for lead in soil and found that no significant changes in concentration occurred within a year of sample collection (U.S. EPA 2005a). EPA generally recommends holding times of no more than 6 months for inorganic contaminants (U.S. EPA 2005a); however, site-specific SAP QAPPs may specify different holding times.

6.13 Assessment of Relative Bioavailability (RBA) of Lead in Soil

Depending on the chemical and physical characteristics of the environmental media matrix and the type of lead present, <100% of lead entering the body through ingestion may be absorbed into systemic circulation (U.S. EPA 2024). This is referred to as the bioavailability of lead—a characteristic critical for both understanding how the body absorbs and reacts to lead exposure, and for determining the risk of detrimental health effects associated with lead exposure (U.S. EPA 2020d). Once absorbed into the body, lead is widely distributed and interacts with the body's chemistry, affecting soft tissues (*e.g.*, kidneys, liver, heart), the brain, and eventually accumulating in the teeth and bones over time (U.S. EPA 2024). Though relatively stable when stored in the bones, it is in equilibrium with blood and its release into the bloodstream is enhanced due to osteoporosis and during pregnancy and lactation (ATSDR 2020). RBA of a contaminant in soil is how much of that contaminant is absorbed into the body from soil compared to how much of that contaminant is absorbed from a reference exposure medium (*e.g.*, food, water) that relates back to the toxicity value of that contaminant. The default RBA of lead for both the IEUBK and the Adult Lead Methodology (ALM) is 60%, based on the mean RBA of a large number of soils (U.S. EPA 2021a). However, the RBA of lead in soils can range from <10% up to 100%. The use of site-specific RBA information greatly improves the accuracy of the HHRA and can result in a PRG that differs substantially from the regional screening level (RSL) or removal management level (RML).

RBA of lead in soil and sediment can be estimated from *in vitro* assays that measure lead bioaccessibility (an *in vitro* measure of the physiological solubility of the lead that may be available for absorption into the body) (U.S. EPA 2020c).[92] EPA SW-846 Method 1340 has been validated as an *in vitro* bioaccessibility (IVBA) assay method to predict the RBA of both lead and arsenic in soil or sediment (U.S. EPA 2012b). EPA SW-846 Method 1340 is a substantially less

[92] https://semspub.epa.gov/src/document/HQ/100002712.

expensive alternative to an animal bioassay for assessing RBA. The relatively low cost of the IVBA assay compared to an animal bioassay, availability of standard operating procedures (SOPs), and availability of public and commercial laboratories where it can be performed allows larger numbers of soil samples to be processed more rapidly for the same cost as a single animal bioassay while reducing animal testing. Using the IVBA assay to evaluate multiple soil or sediment samples at a site can provide a more thorough assessment of site RBA. When using novel media that were not represented in the data used to validate the IVBA assay, however, it is prudent to conduct confirmatory animal RBA bioassays before using an IVBA assay. These may include soils with chemical and physical characteristics outside the domain of soils used to develop and validate the IVBA assay (which included residential soils, mining soils, smelter soils, slag, National Institute of Standards and Technology [NIST] paint, and galena enriched soil). For a list of the validation samples and their characteristics, see U.S. EPA (2007b). EPA is working on assessing the relationship between *in vivo* animal assays and the Method 1340 IVBA and will publish that update at https://www.epa.gov/superfund/soil-bioavailability-superfund-sites. It may also include soils that have received treatments with amending agents that alter mobility or solubility of arsenic or lead. At this time, IVBA methods have not been validated for soil that has received amendments for chemical alteration of soil lead (*e.g.*, phosphate amended soils).

EPA generally recommends that site-specific RBA data be collected at lead-contaminated Superfund removal and remedial sites and RCRA Corrective Action sites using validated *in vitro* (or less commonly, *in vivo*) methods (U.S. EPA 2020c, 2017d). It may also be useful to collect bioavailability data for other purposes, such as pre-NPL listing decision-making. Note that sediment IVBA is for swimming and wading scenarios where young children are exposed to sediments in shallow water, not exposure through fish consumption. EPA provides guidance (U.S. EPA 2020c) on major topics related to collection of information on, and application of, RBA data in HHRA, including: (1) rationale for collecting RBA data to support HHRA; (2) application of IVBA and RBA data in HHRA; (3) evaluation and analysis of IVBA and RBA data for use in HHRA; (4) systematic planning for collection of RBA data; and (5) collection and processing of soil samples for measurement of arsenic and lead IVBA at sites. In the absence of RBA assessments from a validated assay, EPA recommends that the default RBA of 0.6 (60%) be assumed for soil lead at all sites other than firing ranges, where an RBA of 1.0 (100%) should be used (U.S. EPA 2020d). See the Bioavailability Committee website[93] for more information on using bioavailability information in risk assessments.

[93] https://www.epa.gov/superfund/soil-bioavailability-superfund-sites-guidance.

6.14 Evaluating Soil Data and Soil Screening Levels

Data obtained from soil sampling efforts may be used to determine whether mean lead concentrations present in soil pose a potential unacceptable risk to residents, and can further inform risk management decisions. See Section 8.4 for a discussion of sampling for and calculating EPCs. See Section 9.4.1.2 for a discussion of how the EPC is compared to the PRG or cleanup level as a not-to-exceed (NTE) level and Section 9.4.1.3 for a discussion of how the EPC is compared to the PRG or cleanup level as an area-wide average.

OLEM recommends using an RSL[94] for lead in soil at residential sites (Breen 2024, U.S. EPA 2016, 1994a). RSLs, along with RMLs for the Removal Action, are not cleanup levels, but rather guidelines to determine which sites or portions of sites may warrant further study. While residential areas with soil lead concentrations below an RSL/RML generally warrant no further action, some actions may be appropriate in certain situations because the screening level does not generally consider site-specific information, such as soil lead bioavailability information. For example, metallic lead in soils weathers quickly to lead oxide, lead carbonate, and other lead salts that are highly bioavailable. Firing ranges and other locations with metallic lead in soils may benefit from further investigation even where the soil lead concentration is below the RSL/RML.

EPCs are compared to RMLs and RSLs to determine if:

- Removal action may be warranted if media concentrations exceed RMLs[95];
- Further site characterization of risk if media concentrations exceed RSLs; and
- No further action if media concentrations do not exceed RSLs and high bioavailability of lead is not expected.

EPA developed the *Residential Lead Screening Level Checklist* to assist site teams in selection and documentation of the RSL for lead in soil at residential sites (see supporting information at https://www.epa.gov/superfund/updated-soil-lead-guidance-cercla-sites-and-rcra-corrective-action-facilities).

[94] For more information on RSLs, see https://www.epa.gov/risk/regional-screening-levels-rsls-users-guide#lead.
[95] RMLs are only one component evaluated by OSCs in determining whether a removal action is warranted. For instance, OSCs are also required to evaluate the eight factors at 40 CFR 300.415(b)(2). Also, the exceedance of an RML does not always justify a removal action (see RML User's Guide: https://www.epa.gov/risk/regional-removal-management-levels-rmls-users-guide). Conversely, when site concentrations don't exceed RMLs, then a removal action is unlikely to be justified. Except in limited circumstances, sites with soil concentrations above the RSL but below the RML would be referred to another Program (*e.g.*, Remedial, State, Brownfields, etc.) for follow up.

6.15 Dietary Sources of Lead Exposure

The default dietary inputs in EPA's lead risk assessment model (the IEUBK, see Chapter 8) represent national estimates of lead exposure from food. The default estimates are based on lead concentration information from market basket studies conducted by the U.S. Food and Drug Administration (FDA) and food consumption information from the National Health and Nutrition Examination Survey (NHANES).[96] The alternate dietary intake menu includes ingestion of game animals from hunting, fish from fishing, and home-grown fruits and vegetables. This exposure pathway is an alternative approach to substituting for dietary exposure to lead in store-bought food based on information from the FDA. This feature can be used when site-specific data are available to estimate both the concentration of lead in these food sources and the contributions of these food sources to the diet of a typical child resident at the site. Alternatively, the Alternate Source Pathway of the IEUBK model may be used to assess risk for these dietary sources. While this alternative may result in double-counting of lead exposure from dietary sources, it benefits from not requiring professional judgment to determine how much of the diet is replaced by local sources. Consultation with the TRW Lead Committee[97] is available if RPMs or risk assessors have questions about assessing site-specific dietary exposures.

6.15.1 Fish (Fish from Surface Waters Impacted by the Release) and Game (from Hunting within the Site)

When the alternate dietary intake menu mode of data entry is used, the IEUBK model substitutes fish or game for other store-bought meat dishes, so users must estimate fish or game meals as a proportion of total meat meals. For example, in estimating child lead exposure from recreational fishing, appropriate inputs for percent of food class would be 10% for recreational fishing or as much as 50% for high-end cases; note that these may vary depending on site-specific information. Fish collected from the site, or impacted by the site, should represent the types and size class of fish that local people catch and eat. The average concentration of lead in fish as consumed (either fillets or whole fish depending on site-specific information) is entered as micrograms of lead per gram (μg Pb/g) of fish tissue. The analysis should consider the fish consumption habits of residents, since the lead concentration may differ in fish fillets versus whole fish.

[96] https://www.epa.gov/superfund/lead-superfund-sites-guidance.
[97] https://www.epa.gov/superfund/lead-superfund-sites-technical-assistance#:~:text=The%20TRW's%20Lead%20Committee%20reviews,methodologies%20at%20hazardous%20waste%20sites.

In addition, EPA's *Guidance for Assessing Chemical Contaminant Data for use in Fish Advisories Vol. 2* (U.S. EPA 2000b) recommends three-ounces of fish per day (85 grams/day [g/day]) for children as an average. Therefore, consumption of fish meals between the average 3 ounces and an upper bound estimate of 8 ounces (85 and 227 grams, respectively) may also be used in the analysis. Note that fish consumption may differ from the national estimates on a site-specific basis (*e.g*., Native American populations). The RPM/OSC may want to work with the risk assessor to evaluate available studies of similar water bodies and populations to identify ingestion rates based on similarities in fish species, type of water body (*e.g.*, fresh versus salt water, stream versus river, fish advisory present or not), population demographics, potential for response bias, and other characteristics.

Similarly, site-specific information on consumption of hunted game would be used to replace meat intake in the IEUBK model.

6.15.2 Garden Produce

The uptake of metals into plant tissue for most common garden vegetables is not very high and does not contribute significantly to exposure; however, exposures typically come from ingesting soil adhered to produce, garden soil exposure, and handling and tracking contaminated soil into the residence (U.S. EPA 2014a). Vegetables should be scrubbed or peeled before consumption, and hands, clothing, and tools should be cleaned before being brought indoors. See Table 6-3 for recommended Best Management Practices (BMPs) for gardening in lead-contaminated areas to reduce lead exposure in contaminated soil (Brown et al. 2015, U.S. EPA 2014a). Additional information on collecting and utilizing garden data in the IEUBK model can be found in the Guidance Manual for the IEUBK model (U.S. EPA 1994b).[98]

[98] For additional information, refer to: https://www.epa.gov/superfund/lead-superfund-sites-frequent-questions-risk-assessors-integrated-exposure-uptake#garden; https://www.epa.gov/superfund/lead-superfund-sites-guidance#gardening.

Table 6-3. Approaches to Reduce Exposure to Lead in Garden Soil

Techniques	Approaches
Behavioral	• Discard outer leaves of leafy vegetables • Wash produce to remove soil • Peel root crops • Discourage eating soil • Wash hands, toys, pacifiers • Wear gloves • Keep children from entering the garden if contaminant levels are unknown • Minimize soil track-in • Take off shoes, use doormats, and clean floors • Provide alternative safe areas, like a sandbox, for children's play • Locate gardens away from older painted structures, fences, or sheds
Soil remediation	• Request a soil sample test for metals and agronomic parameters before beginning gardening • Adjust soil pH to near neutral (~6.5-7.5), based on findings • Incorporate clean materials (*e.g.*, compost, manure) • Apply mulch to reduce dust and soil splash-back onto crops and reduce exposures • Add phosphate amendments where appropriate • Excavate contaminated soil and place geotextile barriers
Alternate remediation	• Build raised beds with safe materials (*i.e.*, do not use treated lumber, salvaged painted wood, or railroad ties) with a barrier (*e.g.*, landscape fabric) and fill with clean soil • Use containers to grow in clean soil (*e.g.*, 5-gallon buckets that do not leach metals) • Consider other land/location options