Identifying Exposure Units for the Public Health Assessment Process

Citation:
[ATSDR] Agency for Toxic Substances and Disease Registry. 2020. Identifying Exposure Units for the Public Health Assessment Process. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service, September 19.

Contents:

List of Figures

List of Abbreviations

ADS	Associate Director for Science
ATSDR	Agency for Toxic Substances and Disease Registry
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
GIS	geographic information system
PHAGM	*Public Health Assessment Guidance Manual*
PHAST	Public Health Assessment Site Tool
95UCL	95 percent upper confidence limit of the arithmetic mean

1.0 INTRODUCTION

Environmental contamination is found over many different geographical scales, from small localized areas caused by spills to widespread contamination from decades of environmental releases. Many factors influence how people may contact this contamination. For instance, daily routines, personal preferences, cultural practices, permanent fences, and natural barriers all affect where people frequent. Health assessors must bridge both types of information—environmental contamination information and how people come in contact with the contamination in order to evaluate whether exposures present public health hazards. One step in this process is identifying exposure units, which are defined as physical areas where a person's activities result in contact with a contaminated environmental medium. This document presents ATSDR's guidance for defining exposure units for use in the public health assessment process.

Health assessors should use this guidance for the following purposes:

1. To define exposure units for potential or completed pathways.
2. To select representative environmental data for evaluating exposure units.

Other agencies have prepared guidance on defining exposure units for human health risk assessments, but health assessors should not use such approaches unless first approved by an Associate Director of Science (ADS) group.

1.1 When to Use This Guidance

During the public health assessment process, health assessors perform many activities, including developing a conceptual site model, evaluating exposure pathways, compiling and reviewing environmental data, and screening those data against health-based comparison values. ATSDR has developed guidance and other resources to assist health assessors with these and many other steps in the process. For example, Section 6 of ATSDR's *Public Health Assessment Guidance Manual* (PHAGM) (ATSDR 2005) presents guidance on developing conceptual site models and evaluating exposure pathways. ATSDR's web-based application Public Health Assessment Site Tool (PHAST) guides health assessors through the process of screening environmental data.

Exposure units are areas or points of human contact with contaminated media and should be defined as part of the exposure pathway analysis process. When maximum contaminant concentrations in the exposure unit exceed health-based comparison values or meet the criteria outlined in section 7.4 of *PHAGM* (ATSDR 2005), health assessors should calculate exposure point concentrations (EPCs) and exposure doses for the environmental media and exposure pathways of interest for each identified contaminant of concern. Calculated doses are then compared to established toxicity values for cancer and non-cancer health endpoints.

KEY POINT: WHEN TO DEFINE EXPOSURE UNITS?

Health assessors do not need to define exposure units for every site. This step is only needed in cases where potential or completed exposure pathways have been identified. In such cases, health assessors typically define exposure units before screening concentrations against comparison values. Exposure units are *always* defined before determining EPCs for health evaluations.

Defining exposure units is just one step in the overall public health assessment process. This guidance describes the various factors that health assessors should consider when completing this step and provides several examples and case studies on how to define exposure units for various pathways.

1.2 Topics Not Covered by This Guidance

This guidance describes how to define exposure units and then select representative environmental data for evaluating those exposure units. When conducting a public health assessment, the next step in the process is to determine appropriate EPCs for subsequent exposure dose calculations, and health assessors should refer to the following documents for guidance on this step:

- The general approaches for determining EPCs are outlined in: *Exposure Point Concentration Guidance for Discrete Sampling* (ATSDR 2019a) and *Exposure Point Concentration Guidance for Non-discrete Sampling* (ATSDR *in development*). The latter document is currently being developed. Health assessors who need to evaluate data collected via non-discrete sampling methods before the guidance is available should consult with their ADS group.

- Some substances have special considerations beyond those listed in the EPC guidance documents. When evaluating EPCs for dioxins and dioxin-like compounds, health assessors should refer to ATSDR's *Toxic Equivalents Guidance for Dioxin and Dioxin-like Compounds* (ATSDR 2019b). ATSDR is currently developing separate guidance for polycyclic aromatic hydrocarbons (PAHs) (ATSDR *in development)*. Health assessors who need to address PAHs before the guidance is available should consult with their ADS group on preferred approaches.

- When conducting exposure dose calculations for asbestos or lead, health assessors should consult with their ADS group or an ATSDR subject matter expert on preferred EPC approaches.

1.3 How to Use This Guidance

Health assessors will find the following guidance in this document's text:

- Section 2.0 presents background information, including ATSDR's definition of exposure units;
- Section 3.0 outlines ATSDR's guidance for defining exposure units;
- Section 4.0 describes factors health assessors should consider when selecting representative environmental data for the identified exposure units;
- Section 5.0 contains references;
- Appendix A is a glossary of key terms;
- Appendix B provides a flowchart of how exposure units are defined within the public health assessment process; and
- Appendix C presents several case studies.

Further information is provided throughout this guidance in text boxes, as follows:

Key Point
Blue text boxes summarize major elements of this guidance.

Additional Information
Yellow text boxes provide scientific background information on exposure units.

2.0 BACKGROUND

This section presents important background information on exposure units for the public health assessment process, starting with a definition. This section then presents general considerations for defining exposure units. Later sections of this guidance provide more detailed information about applying the exposure unit definition in practice.

2.1 Exposure Unit Definition

An exposure unit is a geographically defined point or area where a person is expected to contact an environmental medium, such as soil, surface water, groundwater, air, or food items (e.g., fruits, vegetables, fish, game). Within this area, people are assumed to move around (or contact the environmental medium of concern) in a manner such that the average concentration[1] of a contaminant is assumed to characterize long-term exposure.

Health assessors should use the flow chart shown in **Appendix B** and consider the following factors when defining exposure units:

- **Exposure units can vary greatly in size.** Exposure unit dimensions depend largely on human activity patterns and access restrictions, which vary considerably across sites. Exposure units may be as small as a single drinking water tap served by a private well or as large as an entire wildlife management zone where hunters have open access. They also may comprise the indoor environment or the outdoor environment.

- **Sites may have multiple exposure units.** The number of exposure units at a site can also vary. For instance, sites with highly localized spills will typically have a single exposure unit, such as a small area of a public beach that had a fuel oil spill. Other sites will have dozens of exposure units, as may be the case for neighborhood-wide surface soil contamination. In this case, each residential yard within the neighborhood may be treated as a separate exposure unit if residents primarily contact soil in their own yards or have different behaviors that can increase or decrease their exposures. For example, some residents may maintain a vegetable garden in their yards while other residents may have small play areas for their children in their yards.

- **Exposure Units are defined by people's activities and not available environmental data.** Health assessors should define the spatial extent of an exposure unit by people's activities and not by where environmental samples have been collected. More specifically, exposure units should be defined based on how a person's assumed daily routines, preferences, and cultural practices affect environmental exposure. This requires careful consideration of the specific site and population being evaluated. For example, health assessors should consider environmental exposure scenarios that are unique to individual Native American tribes (e.g., reliance on hunting of local game and consumption of local fish or use of plants for medicinal purposes) when defining exposure units for sites involving tribal communities. Exposure units should also be defined considering whether any natural or physical barriers exist that might limit their

[1] Health assessors are reminded that average exposures are generally evaluated as the 95 percent upper confidence limit of the arithmetic mean (95UCL) in ATSDR public health assessments. Refer to applicable EPC guidance for more information on appropriate EPC statistics (ATSDR 2019a).

access to certain areas. If available, sensor data (e.g., mobile phone sensor technology) can be used to better understand human activities at the site and help define the boundaries of an exposure unit. An exposure unit might also be spatially defined based on proximity to a certain area regardless of available environmental data (e.g., all homes located downwind of a release). Examples in Sections 3.1 and 3.2 and **Appendix C** demonstrate this point.

- **An exposure unit might have never been sampled.** Prior to screening concentrations against comparison values, the analysis of exposure pathways may reveal incomplete or missing sampling data. In such cases, health assessors may have to define exposure units for potential or completed pathways in areas that have never been sampled. For example, at sites with widespread groundwater contamination, separate exposure units may need to be identified for different private wells that draw from the contamination plume—including private wells that have never been sampled. Section 4.0 lists options available to health assessors for specifying EPCs in cases where exposure units have no environmental samples.

- **Exposure units can vary by conditions of exposure.** Exposure units are defined by areas that people access randomly over time. These areas may differ for acute (1-14 days), intermediate (15-364 days), and chronic exposures (365 days and longer). For example, a health assessor may define two exposure units for a home with a large ½-acre lot with surface soil contamination: the entire lot may be the appropriate exposure unit for chronic exposures but a subset of the lot (e.g., an area where an in-ground pool is dug up) may be appropriate for acute exposures.

GIS and Exposure Units

Health assessors are not required to incorporate exposure units into geographic information system (GIS) maps. However, GIS may be helpful for visualizing and analyzing exposure units, especially for large sites with many exposure units. GIS can be particularly helpful for sites with environmental sampling data in electronic format, because GIS software can readily identify all samples that were collected within specific areas or can be used for analyzing contamination within a medium through interpolation, spatial Kriging, or other modeling.

- **Defining exposure units to inform environmental sampling.** Where possible, health assessors should ensure that environmental sampling programs generate representative data for exposure units. It is optimal when health assessors are involved with a site before sampling occurs (e.g., health assessors may be asked to comment on sampling plans before ATSDR and its partners conduct exposure investigations). In these cases, health assessors should delineate exposure units and attempt to ensure that the proposed environmental sampling generates representative data for those areas. However, in situations where sampling activities have been completed prior to initiation of the public health assessment process, health assessors should make the best use of available information and disclose any uncertainties or data gaps.

2.2 Information Sources to Consider

Defining exposure units should be a straightforward process—and one that does not take too much time to complete. Health assessors should consider the following information sources when defining these areas:

- Conceptual site model and exposure pathways analysis;
- Observations made and pictures taken during site visits;

- Review of maps and aerial photographs;
- Discussions with residents, community groups, or tribal leaders;
- Review of institutional controls (e.g., fishing advisories, hunting regulations) ;
- Physical barriers; and
- Discussions with officials from other agencies (e.g., EPA; state, tribal, and local health agencies).

2.3 Exposure Units vs. Operable Units vs. Decision Units

When reviewing sites and defining exposure units, health assessors may encounter terminology that sounds like exposure unit but has considerably different meaning. Sites on the National Priorities List, for example, are often divided into "operable units." This term simply refers to different areas of investigation within a contaminated site that are typically defined in the remedial investigation phase. As such, there should be no expectation that a sites' operable units coincide with exposure units, though this may be the case in some circumstances.

Similarly, health assessors may come across the term "decision unit" when reviewing site documents. This term is used primarily in the context of incremental sampling methodology projects—a form of non-discrete sampling applied to soils that is discussed extensively in other ATSDR guidance (ATSDR *in development*). The decision unit refers to the area covered by a given round of incremental sampling. Health assessors should not infer that decision units are identical to exposure units, but again, this may be the case in some circumstances.

Exposure/Operable/Decision Units
Health assessors should follow this document's guidance to define *exposure units* for contaminants of concern in completed or potential exposure pathways. *Operable units* and *decision units* are different terms defined for different purposes and should not be assumed to coincide with *exposure units*.

2.4 Documenting Exposure Units in Public Health Assessment Reports

The term "exposure unit" is used as part of the public health assessment methodology. However, health assessors **do not** need to specifically use the words "exposure unit" in public health assessment or health consultation documents. Exposure units **do** need to be implicitly described in these documents though, and in terms that the public can relate to, such as residential yards, lots, or drinking water wells. All written products must be abundantly clear about the geographical areas to which health conclusions apply, even if these documents do not specifically use the term "exposure unit."

3.0 GUIDANCE RECOMMENDATIONS FOR DEFINING EXPOSURE UNITS

This section presents guidance recommendations for defining exposure units for two scenarios based on how environmental contamination aligns with where people contact environmental media. **Appendix B** provides a flowchart of how exposure units are defined within the public health assessment process. Examples illustrate general concepts; and **Appendix C** presents specific case studies to highlight delineation of exposure units for different environmental media.

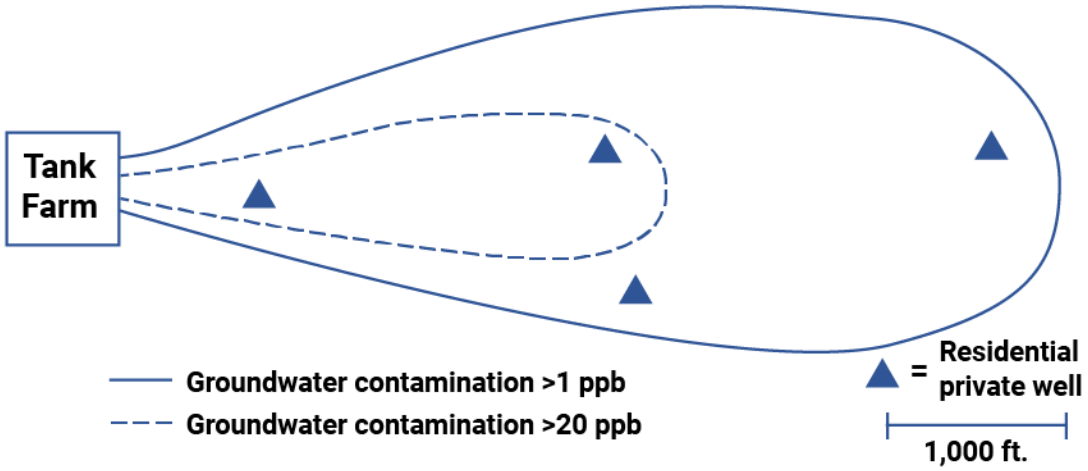
3.1 Exposure Units within Larger Areas of Environmental Contamination

Commonly, health assessors will encounter environmental contamination that spans areas much larger than exposure units. When this occurs, health assessors often define multiple exposure units within the contaminated area to account for the different exposures that occur. In these cases, exposure units

must correspond to points of contact with contaminated media (e.g., drinking water wells) or areas of contact (e.g., a stretch of beach, a school yard).

For example, consider the scenario depicted in Figure 1, in which a leaking storage tank caused a large groundwater contamination plume that currently affects four private wells at four different homes. Please note that the isopleths shown in Figure 1 were determined from monitoring well data (not shown). The drinking water contamination levels are highly variable across the homes. The health assessor has determined that this is a completed exposure pathway. How should exposure units be defined in order to appropriately evaluate exposure to residents who drink from private wells?

Figure 1. Defining Exposure Units – Example 1



What the health assessor SHOULD DO…	*What the health assessor SHOULD NOT DO…*
Define four separate exposure units—one for each of the different private wells. This decision assumes that residents routinely obtain their drinking water from their own private wells.	Combine the four private wells into a single exposure unit. Doing so incorrectly assumes that, over time, residents obtain their drinking water at random from across the four wells.

In this example, health assessors should consider where residents routinely obtain their drinking water and assign exposure units accordingly. That decision should not be influenced by the magnitude of groundwater contamination. Once the exposure units are selected—in this case, the four drinking water wells—the health assessor would then proceed with separate evaluations for each of the four exposure units. For each exposure unit, health assessors would identify contaminants of concern; determine the appropriate EPC to use for each contaminant of concern and exposure pathway of interest; calculate the exposure dose based on that EPC; and then conduct their health evaluations based on the calculated dose. In this example, the process for defining exposures units would be the same for the soil vapor intrusion pathway, which may also be of concern in these homes.

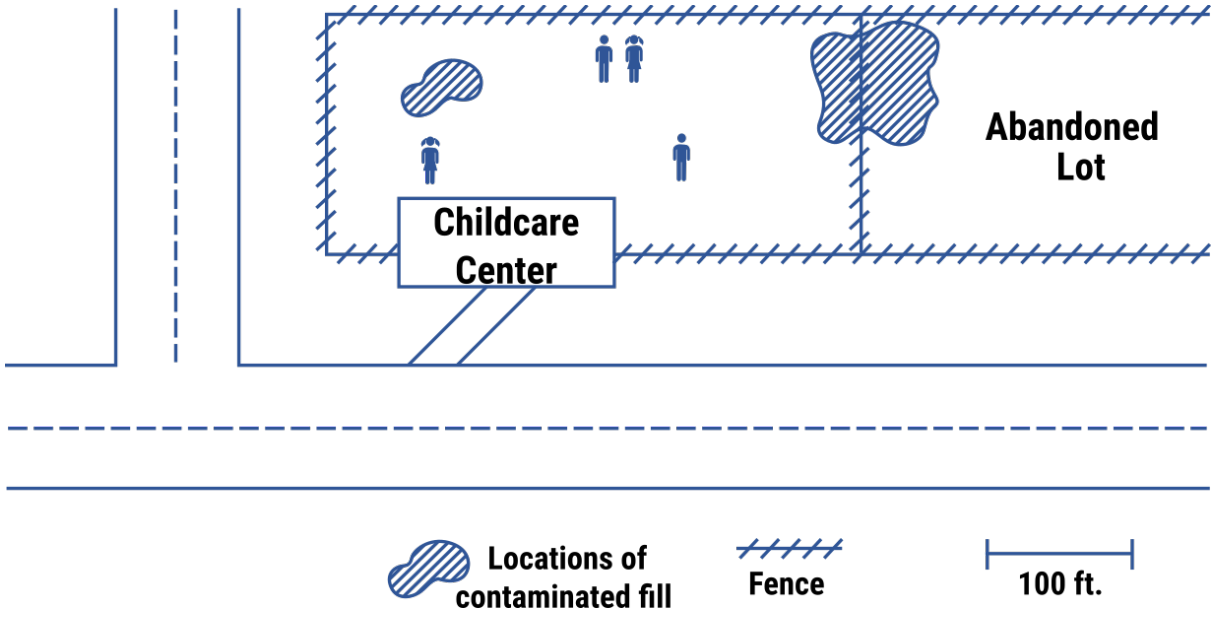
3.2 Contaminated Areas within Exposure Units

Another common scenario that health assessors will encounter is environmental contamination that falls within the boundaries of exposure units. In these cases, health assessors should define the

exposure unit based on areas where people contact the environmental medium of concern—which might include both contaminated and non-contaminated areas.

The scenario depicted in Figure 2 illustrates this point. The figure depicts a childcare center with a large backyard that is completely open for children to play in. The backyard contains two highly localized areas where contaminated fill was previously disposed. How should exposure units be defined for evaluating exposures for the childcare center attendees?

Figure 2. Defining Exposure Units – Example 2



What the health assessor SHOULD DO…	*What the health assessor SHOULD NOT DO…*
Define one exposure unit for the entire backyard area of the childcare center. This decision assumes that, over time, children play in different areas throughout the backyard.	Define two exposure units that cover only the areas of contamination. Doing so assumes that the children only play in those areas and would lead to an overestimate of actual exposures.

In this example, health assessors should define exposure units based on areas where the children play, not on the areas with contamination. If the children indeed play throughout the backyard of a property, the entire backyard area should be the exposure unit—regardless of whether the backyard has "hot spot" contamination or widespread contamination. If sampling was not representative of the entire backyard (e.g., biased towards areas of known contamination) then this should be discussed as a limitation in the assessment of the data. Based on the exposure unit definition, the health assessor would then estimate EPCs for contaminants of concern for the entire backyard based on the appropriate guidance for doing so (e.g., ATSDR 2019a).

Note: For the case illustrated in Figure 2, if children preferentially and routinely access certain areas of the backyard (e.g., a specific sandlot) or never access other areas of the backyard (e.g., due to weed overgrowth), then the health assessor would be justified in selecting a smaller portion of the backyard as the exposure unit. Similarly, if behavior assumptions vary for different parts of the backyard, the health assessor may consider dividing the backyard into multiple exposure

units (e.g., if younger children play on one side of the yard and older children play on the other). Health assessors should also be mindful of possible land use changes when defining exposure units (e.g., if weed overgrowth in an area of the backyard was cleared). If land uses were to change so that an exposure unit for a different scenario could also be assigned, health assessors should identify these areas as potential exposure pathways.

4.0 GUIDANCE RECOMMENDATIONS FOR SELECTING REPRESENTATIVE ENVIRONMENTAL DATA

This section describes three principal options for selecting an exposure unit's environmental data:

- **Use environmental sampling data collected within the exposure unit.** Consistent with recommendations in Section 5.1 of PHAGM, whenever possible, health assessors should base their exposure evaluations on representative environmental sampling data collected within exposure units. This preference reflects the fact that sampling data—as opposed to modeling data—are direct measures of the levels of contamination to which people may be exposed. Health assessors should also ensure an exposure unit's sampling data are valid before using them in the EPC calculations. Case studies 1 and 2 in **Appendix C** show examples of defining an exposure unit and then selecting environmental sampling data collected within the exposure unit for EPC calculations.

  Note that when defining exposure units for the inhalation pathway for outdoor air, health assessors must address several additional matters that are specific to this medium (e.g., spatial and temporal variability). Some of these matters are discussed in ATSDR's EPC Guidance for Discrete Sampling (ATSDR 2019a) and EPC Guidance for Non-discrete Sampling (ATSDR *in development*). For additional information, health assessors should consult with their ADS group.

- **Use environmental sampling data collected outside the exposure unit**. In cases where no samples have been collected from an exposure unit or the data are incomplete, health assessors should consider whether valid environmental sampling data from other locations can inform the health assessment process, particularly for evaluating fate and transport relating to an exposure pathway. For example, for an un-sampled private well being evaluated due to groundwater contamination concerns, health assessors may use sampling data from a nearby groundwater monitoring well as a basis for determining whether a potential exposure pathway exists.

  In such cases, health assessors should carefully review available information on the monitoring well and groundwater flow direction. If they decide to use data from a nearby well, they should provide their rationale for making such a selection (e.g., the monitoring well was screened from the same aquifer and depth, the monitoring well was located between the private well and the source of contamination, groundwater flows from the source of contamination toward the private well) and they should also consider recommending sample collection within the exposure unit. Health assessors should not assume that an un-sampled private well is contaminated because a nearby well is and should not calculate an EPC based on these data. Case study 3 in **Appendix C** provides an example of defining an exposure unit and then selecting environmental sampling data collected outside the exposure unit to inform EPC calculations.

- **Use environmental modeling data.** In some cases, sampling data may be insufficient—whether spatially or temporally—to characterize contamination levels in an exposure unit. Furthermore, sometimes health assessors are only provided with modeled data by external partners (e.g., enforcement agencies) to assess potential health risks. In such cases, health assessors may use modeled data to fill data gaps over space and time. In addition to providing insight into potential exposures over time or geographic area, modeled data are valuable for the purposes of defining the spatial bounds of exposure units.

  Section 5.2 of *PHAGM* describes the nuances of using modeling data in public health assessments. Acknowledging the assumptions and uncertainties of the model, the many limitations of making health calls based on modeling data alone, and recommending sampling in cases where air measurements are limited or missing are important considerations when using models in the health assessment process. If needed, health assessors should consult with subject matter experts when reviewing specialized models and highly technical applications and consider recommending that sampling take place to reduce uncertainties or address limitations in modeled data. Case studies 4 and 5 in **Appendix C** show examples of defining an exposure unit and then selecting environmental modeling data within the exposure unit for EPC calculations.

5.0 REFERENCES

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005. Public Health Assessment Guidance Manual (Update). Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2016. Evaluating Vapor Intrusion Pathways: Guidance for ATSDR's Division of Community Health Investigations. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2019a. Exposure Point Concentration Guidance for Discrete Sampling. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2019b. Toxic Equivalents Guidance for Dioxin and Dioxin-like Compounds. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

[ATSDR] Agency for Toxic Substances and Disease Registry. *In development*. Exposure Point Concentration Guidance for Non-discrete Sampling. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

[ATSDR] Agency for Toxic Substances and Disease Registry. *In development*. Guidance for Calculating Benzo(a)pyrene Equivalents for Cancer Evaluations of Polycyclic Aromatic Hydrocarbons. Atlanta, GA: U.S. Department of Health and Human Services, Public Health Service.

Appendix A: Glossary

Decision Unit. This term is used primarily in the context of incremental sampling methodology projects—a form of non-discrete sampling applied to soils. The decision unit refers to the area covered by a given round of incremental sampling. Health assessors should not infer that decision units are identical to exposure units, but again, this may be the case in some circumstances.

Exposure Point Concentration (EPC). The representative contaminant concentration within an exposure unit or area in an exposure pathway to which receptors are exposed for acute, intermediate, or chronic durations during the past, present, or future.

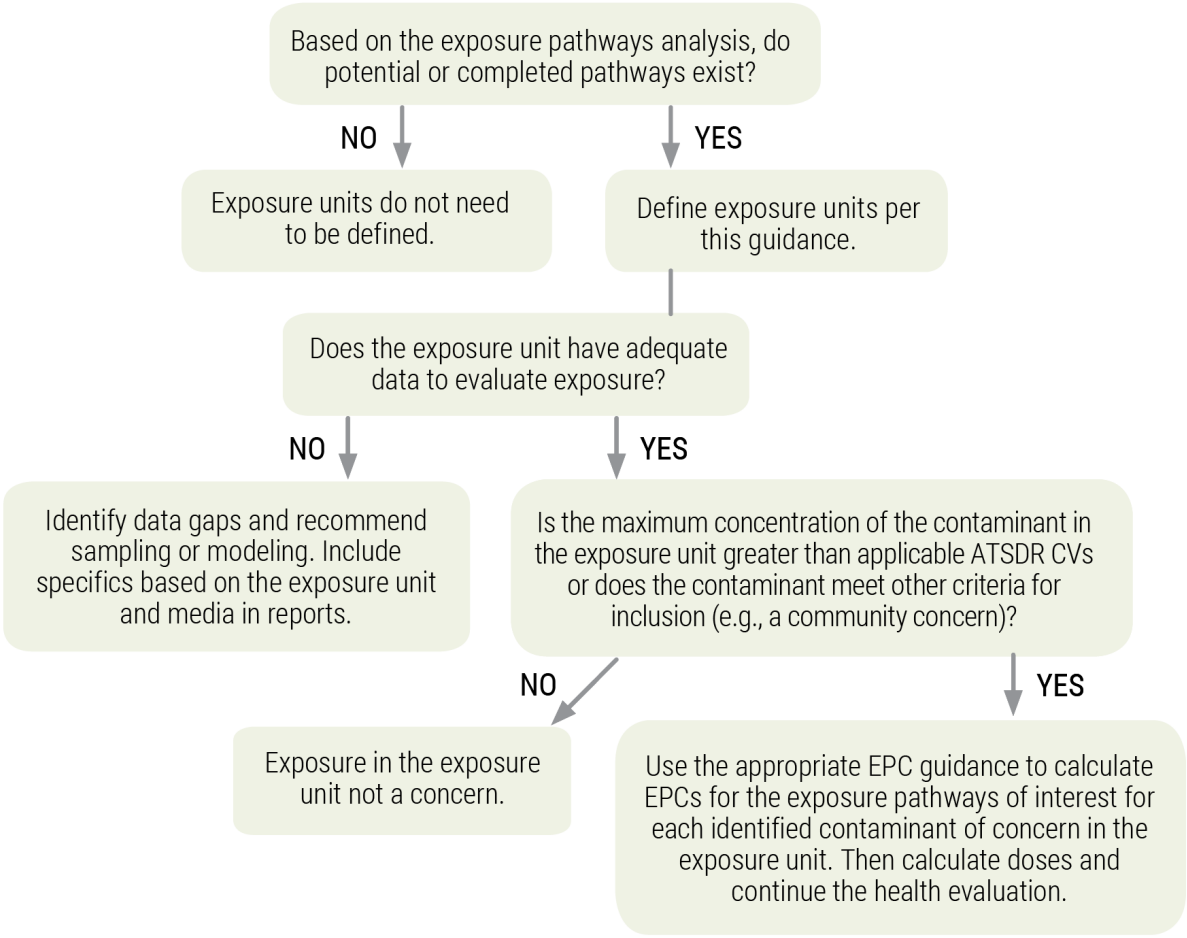
Exposure Unit: A defined area where people may be exposed to one or more environmental media. Within this area, people are assumed to move around (or contact the environmental medium of concern) in a manner that it is assumed the arithmetic mean (average) concentration characterizes long-term exposure.

Geographical Information System or GIS. A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data. The key word to this technology is Geography – this means that some portion of the data is spatial. In other words, data that is in some way referenced to locations on the earth.

Isopleths. A line on a map connecting points at which a given variable has a specified constant value.

Operable Unit. This term simply refers to different areas of investigation within a contaminated site or issues at a contaminated site that are typically defined in the remedial investigation phase. As such, there should be no expectation that sites' operable units coincide with exposure units, but this may be the case in some circumstances.

Appendix B: Process for Evaluating Exposure Units



Appendix C: Exposure Unit Case Studies

This appendix presents five case studies to illustrate proper delineation of exposure units for the public health assessment process. The case studies are organized by environmental medium: (1) surface soil; (2) outdoor air; (3) surface water, sediment, and biota; (4) groundwater; and (5) indoor air. Additionally, these case studies outline specific considerations for selecting environmental data within the identified exposure units, using the same two general scenarios outlined in Section 4.0 of the guidance.

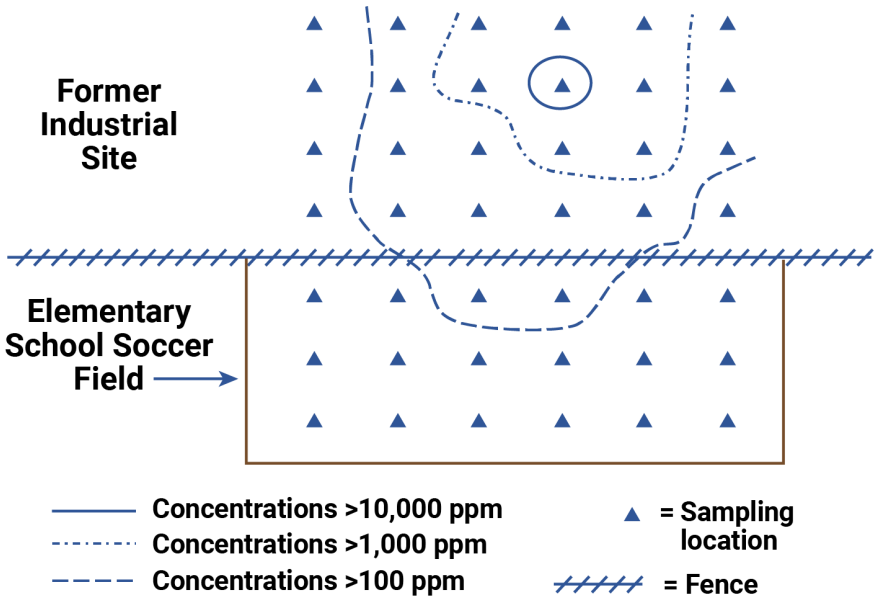
These case studies are intended to show some common issues that health assessors face when defining exposure units for different pathways, but they do not account for all possible site-specific scenarios.

Case Study 1. Exposure Unit Delineation for a Surface Soil Contamination Scenario

Background: Consider an elementary school with a soccer field adjacent to a former industrial site with surface soil contamination (see Figure 3). A secure barbed wire fence prevents students from accessing the industrial site property, and no evidence of trespassing has been observed. During a recent study, facility consultants collected more than 40 surface soil samples around an area of the former industrial site where there was suspected contamination and throughout the adjacent soccer field.

The measured contamination levels were found to be greatest at the site of a former drum storage area (>10,000 ppm) and decreased with distance from this location. Some site-related contamination above the health-based comparison value (>100 ppm) extended to an offsite area in part of the soccer field. Surface soil ingestion among the elementary school children who routinely play on the soccer field was identified as a completed exposure pathway that required a health evaluation.

Figure 3. Defining Exposure Units – Soil



Defining the exposure unit: For the pathway of interest, the exposure unit is the area that the children routinely access—the entire soccer field. Because the fence prevents access to the former industrial site,

that area should not be included in the exposure unit, even though higher contamination levels were observed there.

Selecting data for EPC calculations: This scenario presents a case where the available sampling data appear to be sufficient for characterizing contamination in the exposure unit. When determining the EPC for the exposure unit, the health assessor should only consider measurements from samples collected on the soccer field.

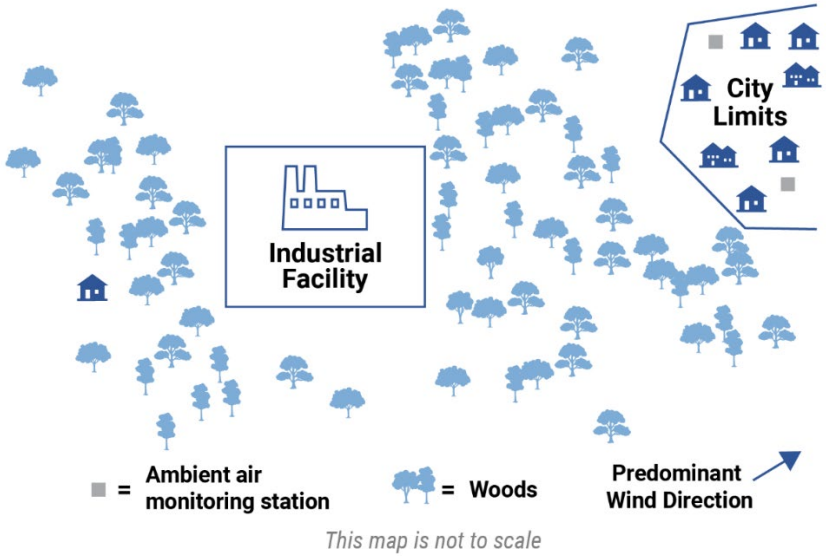
Note: If the health assessor identified a separate exposure pathway for workers who access the former industrial site, the exposure unit and data for EPC calculations for that pathway would be based on the onsite areas that the workers access.

Case Study 2. Exposure Unit Delineation for an Outdoor Air Contamination Scenario

Background: Consider an industrial facility located adjacent to a sparsely populated rural area with one home located southwest of the facility and a small city located more than 1 mile northeast of the site (see Figure 4). The two ambient air monitoring stations located within the city limits monitor for regional air pollutants including sulfur dioxide and fine particulate matter, which are also associated with emissions from the industry and appear to be greater than other regional monitors. Air sampling has never occurred between the facility and the home located southwest of the facility.

The health assessor has reviewed available meteorological data and determined that the predominant downwind direction is from the southwest to the northeast, or towards the small city; however, these data also showed that a secondary downwind direction is southwest towards the one home located in that direction.

Figure 4. Defining Exposure Units – Outdoor Air



Defining exposure units: Based on the information above, the health assessor determined that inhalation of industrial-related air emissions is a potential exposure pathway for the one home located to the southwest of the facility and a completed pathway for all homes located within the city limits. In

this case, the health assessor should assign two exposures units; one for the single home located southwest of the facility and one for the homes located within the limits of the nearby city.

Selecting data for EPC calculations: For the exposure unit defined by the city limits, the health assessor should calculate the EPC using data from the two ambient air monitoring stations. The health assessor should be mindful of the fact that the two stations operate on different schedules and therefore should not assign each measurement equal weight when averaging results. ATSDR's EPC Guidance for Non-discrete sampling data provides details on how data should be processed in such cases (ATSDR *in development*). For additional information on evaluating environmental data for the air exposure pathway, health assessors should contact their ADS group, until specific guidance on this topic is available.

For the exposure unit that corresponds to the one home located southwest of the facility, site-related air quality impacts could be considerably higher than what has been measured within the city limits due to the facility's proximity to the home; however, this needs to be verified since the home is in a secondary downwind direction. The ambient air monitoring data from the two ambient air monitoring stations located in the nearby city may not be representative of this exposure unit. The health assessor should therefore consider recommending additional sampling, at a minimum, on the southwest fence line of the industrial facility to evaluate any potential exposures for residents of this home.

Case Study 3. Exposure Unit Delineation for a Surface Water, Sediment, and Biota Contamination Scenario

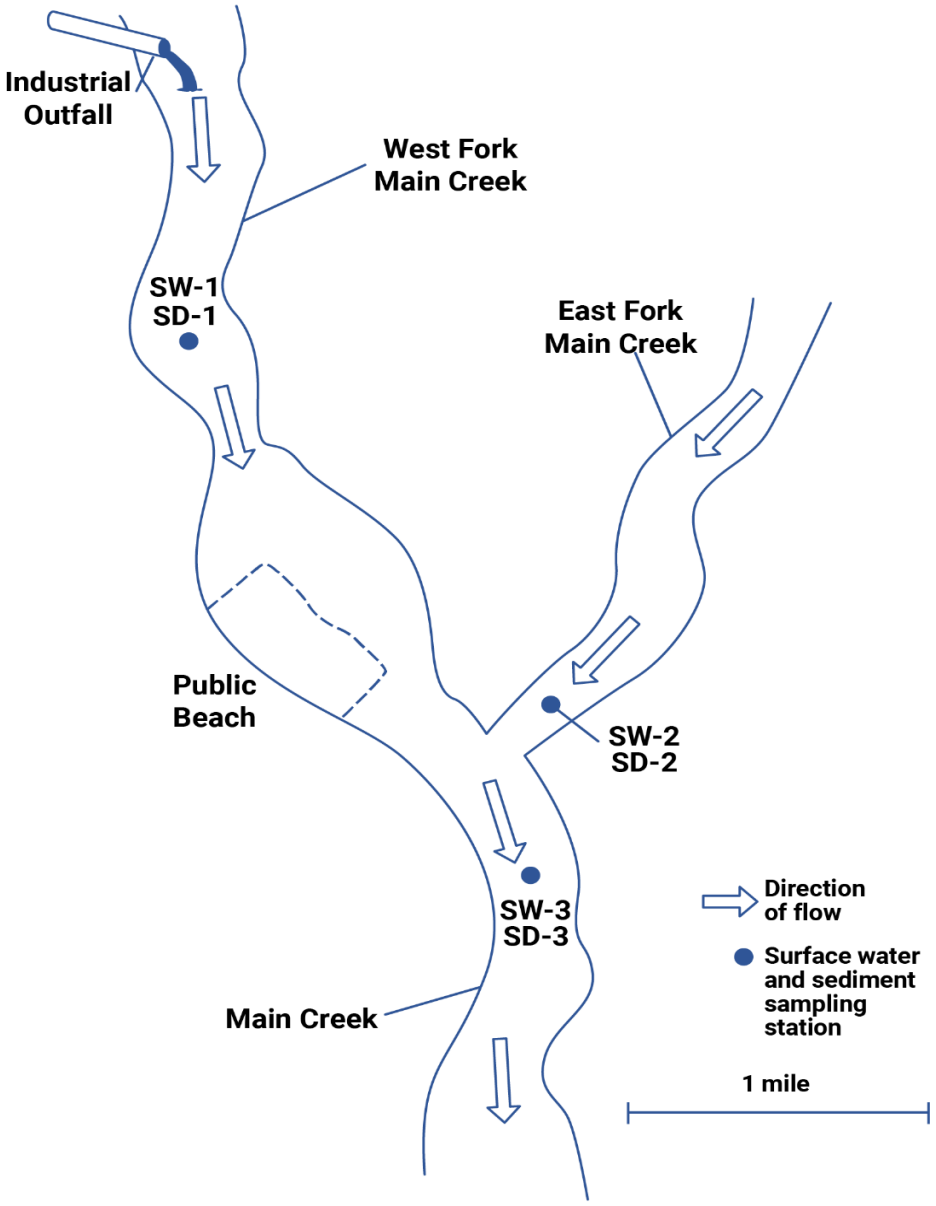
Background: Consider a situation in which an industrial outfall releases a contaminant of concern at an upstream location of West Fork Main Creek (see Figure 5). The contaminant is a synthetic chemical that is not released from any other sources in the area. West Fork Main Creek flows several miles between the industrial facility and the confluence with East Fork Main Creek, at which point the surface water is known as Main Creek and flows to the ocean. Both West Fork and East Fork have comparable flow rates. Recreational uses of the surface waters are limited to a public beach located on the West Fork, and other areas of the creek are not readily accessible with only limited evidence of occasional use for fishing.

After reviewing site data, the health assessor has determined that dermal contact and incidental ingestion of surface water and sediment among beachgoers is a potential exposure pathway. The public beach has a designated swimming area marked by buoys. There are no major tributaries to West Fork between the industrial outfall and the public beach. In addition to potential exposures at the public beach, the health assessor determined that trout fishing occurs in this area and that people generally do not fish from the banks but do so by wading into all areas of the creek (i.e., West and East Forks and Main Creek). For this scenario, the health assessor similarly identified dermal contact and incidental ingestion of surface water and sediment as potential exposure pathways. Consumption of trout (biota) caught in the creeks was further identified as a potential exposure pathway.

Three sampling stations, where surface water samples (SW-1, SW-2, and SW-3) and sediment samples (SD-1, SD-2, and SD-3), are routinely collected and analyzed for the contaminant of concern are located on these creeks.

Defining exposure unit: The exposure unit is defined by locations where people frequent—and not by where sampling occurred. Therefore, for the sediment and surface water exposure pathways for beachgoers in this evaluation, the appropriate definition of the exposure unit is the designated swimming area at the public beach. For the fishing scenario, exposures to sediment and surface water could occur at locations throughout the three creeks. The health assessor should therefore define this larger exposure unit for these potential or completed exposure pathways. For consumption of trout, the health assessor should consider the entire area where trout are expected to feed and swim (i.e., the home range or territory of the trout). Since trout swim upstream, for example, the exposure unit boundary may extend upstream of the outfall location.

Figure 5. Defining Exposure Units – Surface Water, Sediment, and Biota



Selecting data for Exposure Unit and EPC calculations: Surface water and sediment data are available from three sampling stations. For evaluating beachgoer exposures, the health assessor should consider the proximity of the public beach to the sampling locations and the outfall. Although SW-2/SD-2 appears to be closest to the exposure unit, it is not appropriate for characterizing exposures at the public beach: SW-2/SD-2 should not be used because contaminants from the industrial outfall would not flow upriver into this tributary. Moreover, SW-3/SD-3 should not be used because the concentration of the contaminant in Main Creek is expected to be considerably lower than the concentration in West Fork Main Creek, due to the dilution from East Fork Main Creek.

Even though SW-1/SD-1 is located further from the public beach than SW-2/SD-2 and SW-3/SD-3 and even though SW-1/SD-1 is not located within the exposure unit, the health assessor might consider using those sampling data to preliminarily characterize contamination in the exposure unit. For surface water, there are no major tributaries diluting contamination levels between the SW-1 sampling location and the public beach, and the contaminant of concern in this case is unique to the industrial outfall located upstream of this location. For sediment, there are several other considerations. Deposition of contaminants to sediment depends on the chemical and physical properties of the contaminant, flow characteristics of the creeks, and the nature of the creek bed. Depositional areas in rivers may have considerably higher contamination levels than erosional areas. In this case, sediment data from the SD-1 sampling location may be a suitable representation for the exposure unit if the sample location is in a low-flow, depositional areas of the river, where site-related contamination is expected to be highest.

Note: If the contaminant of concern was measured in samples collected from location SW-1/SD-1 at concentrations that are not of public health concern, the health assessor may conclude that public health is likely not of concern downstream at the beach. However, if routine sampling at this location showed levels of health concern for either of these media, a recommendation for sampling at the beach area might be appropriate.

For the fishing scenario, the health assessor would consider potential exposures to surface water and sediment based on all of samples taken at the three locations (even those collected in the East Fork of the Main Creek). For evaluating consumption of fish, the health assessor should define the exposure unit the same as was done for the surface water and sediment pathway and request that fish sampling be conducted.

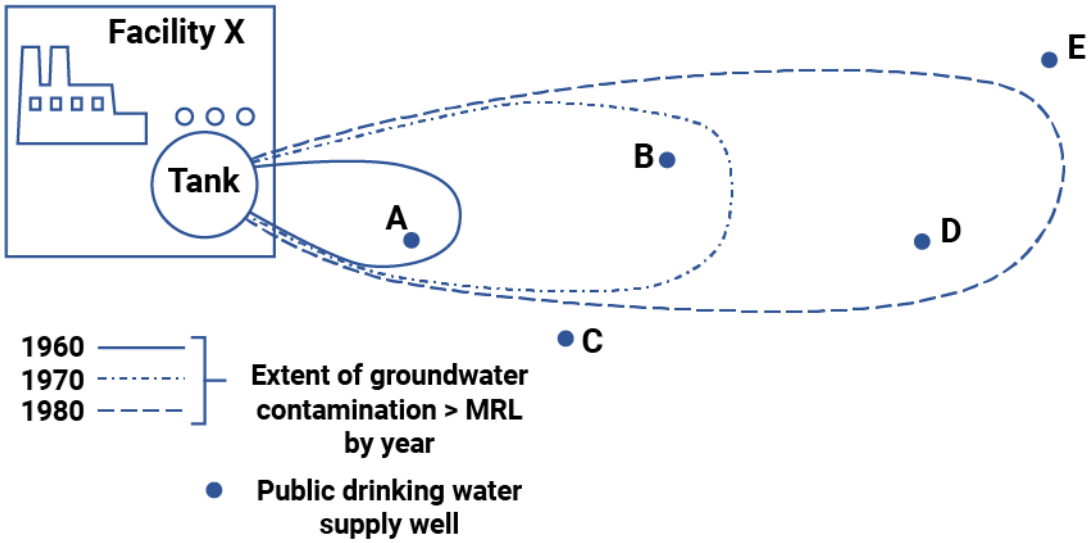
Case Study 4. Exposure Unit for a Groundwater Contamination Scenario

Background: Consider an industrial facility (Facility X) that had a leaking underground storage tank. The leak caused an organic solvent to contaminate groundwater, and the plume extended more than 3 miles offsite before it was first detected in the 1980s (see Figure 6).

The community where Facility X is located has a municipal drinking water supply that is served by five groundwater wells (A-E). Over the years, water has been pumped from these wells at varying rates, and the water is mixed at the local utility before distribution to customers. The utility has very detailed records of well-specific pumping rates over the entire history of operation; and researchers recently used sophisticated hydrogeology models to “hind-cast” the groundwater contamination levels. Wells A, B, and D have been affected by the plume at different time frames. As soon as the contamination was detected, the affected wells were decommissioned and drinking water was provided only by wells outside the plume (i.e., Wells C and E).

The health assessor identified ingestion of contaminated drinking water as a completed exposure pathway, with the principal concern being past exposures.

Figure 6. Defining Exposure Units – Drinking Water



Selecting data for EPC calculations: No sampling data were collected during the time frame of interest for this exposure pathway. While the modeling study characterized groundwater contamination levels over time, those results are not representative of tap water concentrations due to the mixing of groundwater from multiple wells. However, the health assessor combined (a) the groundwater modeling results with (b) another model that combined the well-specific pumping rates over time and the groundwater modeling results to determine scientifically defensible estimates of drinking water concentrations—and how they varied over decades. This case study illustrates an example in which modeling results can be used to determine EPCs for exposure units.

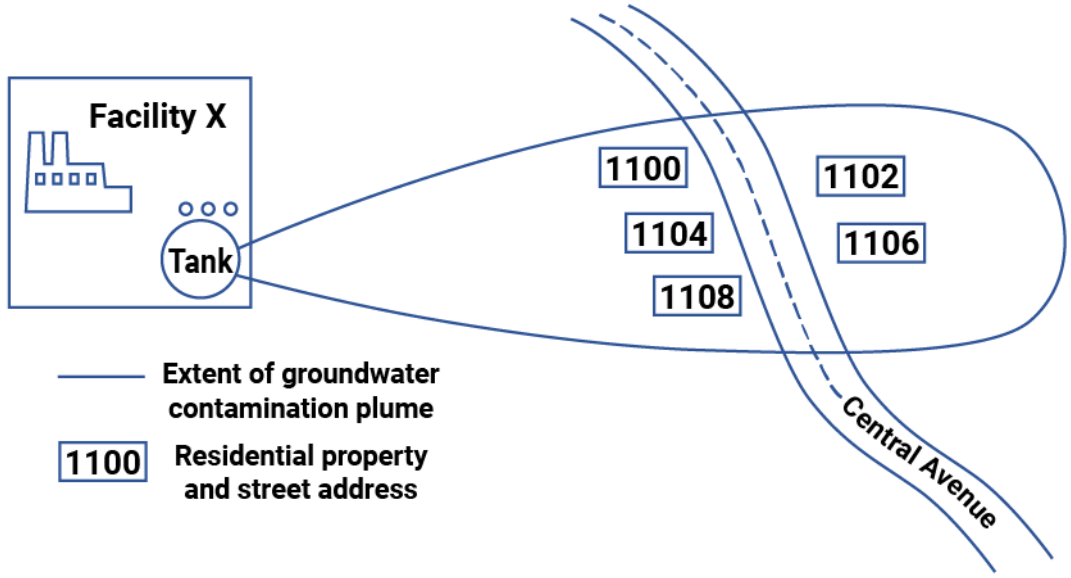
Case Study 5. Exposure Unit for an Indoor Air Contamination Scenario

Background: Consider the same facility, community, and groundwater contamination identified in the previous example (see Figure 7). In the 1990s, after the drinking water supply contamination issues were addressed, five homes were constructed along Central Avenue in an area above the groundwater plume. The homes were constructed by the same developer and have consistent designs, including unfinished basements. Indoor air samples were collected at four of the five homes, but one home (1102 Central Avenue) was not sampled.

Moreover, the extent of the groundwater plume has been extremely well characterized since the early 1990s, and soil gas measurements above the contaminated groundwater are available for all five homes. These sampling results suggest the potential for intrusion of volatile groundwater contaminants into the

homes. Accordingly, the health assessor identified vapor intrusion as a completed exposure pathway that required further evaluation.

Figure 7. Defining Exposure Units – Indoor Air



Defining exposure unit: The health assessor should designate the indoor air in each home as its own exposure unit. Even though the indoor air concentrations of the contaminant of concern may be similar across the homes, they should be evaluated separately because (a) exposure units are defined by locations where people spend their time and not on contamination levels and (b) each home may have unique assumptions that need to be factored into the exposure dose calculations (e.g., some homes might have short-term tenants while other homes may have seasonal occupants, some homes might have child residents, some homes may have additional indoor air sources, like paint cans).

Selecting data for EPC calculations: The indoor air sampling results should be used as the EPC for the four houses that were evaluated. Although no indoor air sampling data are available for determining EPCs at the home at 1102 Central Avenue, the health assessor has access to data characterizing all factors known to affect vapor intrusion, as well as data from comparable properties. In this case, the health assessor may choose to run a health-protective vapor intrusion model for an initial estimate of EPCs—and then decide whether to recommend sampling to further characterize the indoor air concentrations at this property. Any modeling used in this scenario should follow specifications outlined in ATSDR's vapor intrusion guidance (ATSDR 2016). In this case, health assessors could use the soil vapor intrusion groundwater and soil gas screen values to evaluate this potential pathway.

Like case study 4, this case study illustrates an example in which modeling results can be used to determine EPCs for exposure units.