State of Hawaii, Department of Health

HEER Office

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SECTION 3

SITE INVESTIGATION DESIGN AND IMPLEMENTATION
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3.0 SITE INVESTIGATION DESIGN AND IMPLEMENTATION

This Section of the Technical Guidance Manual (TGM) provides an overview of the Site Investigation element of the site assessment process (Figure 3-1; refer also to Figure 2-1 in Section 2).

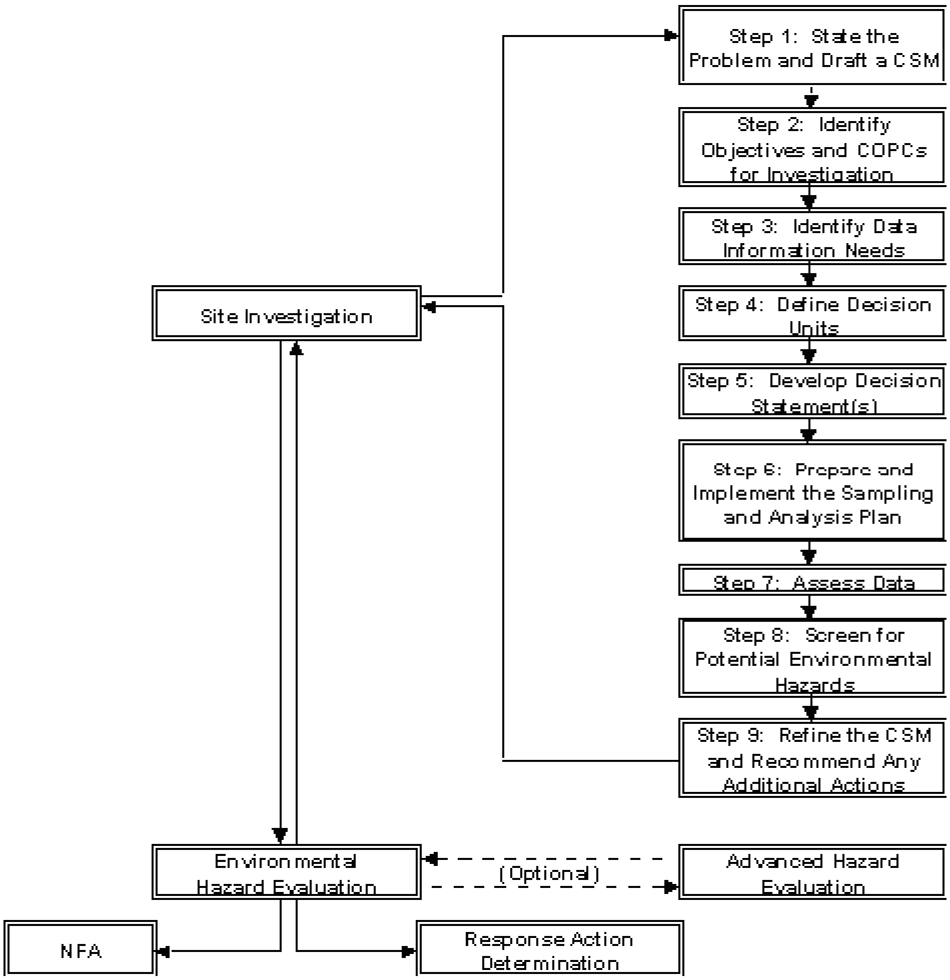

Figure 3-1. Expanded Overview of the Site Assessment Process No Further Action (NFA) letter recommended, which may be requested from HEER Office if site data passes the EHE. Coordination with the HEER Office and Response Action Determination required if site data fail the EHE.

The steps outlined above for implementation of a site investigation are discussed in Subsection 3.2. A site investigation is conducted in order to collect environmental data, evaluate the extent and magnitude of site contamination ("How bad is it?") and support decision-making ("What needs to be done?"). Site investigations can be carried out at different stages of the State Contingency Plan (SCP) process (refer to Subsection 2.1) in order to answer key questions, such as:

- Has a hazardous substance release occurred at the site?
- What is the extent and magnitude of contamination caused by the release?
- Does the release pose an environmental hazard under current or potential future site conditions?

- What method should be used to remediate this site?
- Has the cleanup eliminated the environmental hazard?

The scope and detail of the site investigation will vary from site to site, depending on the questions the investigation is intended to answer and the site complexity. A **systematic planning approach** is recommended to ensure that the data collected during the site investigation are of the type and quality needed to meet the overall site assessment objectives. In addition, the Site Investigation and Environmental Hazard Evaluation (EHE, see Section 13) stages of the site assessment process are necessarily interlinked and iterative (refer to Figure 3-1). The EHE is continually updated as additional site investigation data are obtained. These updates are used to guide and support further site investigation as needed.

For example, detection of high levels of tetrachloroethylene in groundwater during a site investigation could suggest vapor intrusion as a potential environmental hazard (e.g., groundwater action level for vapor intrusion exceeded). This could trigger the collection of soil gas samples in the source area as well as beneath and nearby existing buildings. Under some circumstances the resulting data could trigger the need for indoor air data and/or a review of the building ventilation system. This could then lead to the need to seal floors in order to prevent the potential intrusion of vapors into the building.

Linking the Site Investigation and Environmental Hazard Evaluation stages of the process in this manner from the very beginning of the project improves the effectiveness and efficiency of the overall site assessment process. This in turn helps to expedite completion of the project, minimize disruptions in site use and delays in site redevelopment.

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3.1 SITE INVESTIGATION SCOPING

The first step of a **systematic planning approach** to site investigations is the effective scoping of available information and current site conditions in order to identify potential environmental problems at a property and develop an initial, Conceptual Site Model (CSM) (see Figure 3-1). This includes:

- Review applicable regulations and guidance (see Sections 1 and 2);
- Review site history and existing data;
- Consult with stakeholders.

The information is used to develop a preliminary CSM (see Subsections 3.2.1 and 3.3), identify potential environmental problems and develop the site investigation approach, all of which are essential components of the Sampling and Analysis Plan (see Subsections 3.2.1 and 3.6).

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3.1.1 REVIEW SITE HISTORY AND EXISTING DATA

Existing reports and other records can provide significant information about site characteristics and environmental issues. Previously prepared Phase I and Phase II environmental site assessments (ESAs) may be of significant value. Phase I ESAs are designed to identify potential environmental issues at a site based on field inspections, interviews, and a review of existing documentation. These reports are often required by legal and financial institutions to support property sales or other transactions (e.g., refinancing or facility expansions). Phase II ESAs are conducted to follow up on Phase I findings through the collection, analysis and evaluation of soil, groundwater, soil gas or other types of environmental samples (e.g., lead and asbestos testing of building material). Phase I reports are often confidential and may not be available in public files for the property. Phase II reports might also be confidential, especially if prepared by a perspective purchaser rather than the building owner or operator.

If a Phase I ESA is not available for the site, or if one is available but out-of-date, then a review of site records that follows the Standards for Conducting All Appropriate Inquiries 40 CFR Part 312 (also described in American Society of Testing and Materials [ASTM] E1527-13(ASTM, 2013) should be carried out. The types of records described by 40 CFR Part 312 include:

- Physical setting sources (e.g., topographic maps and area-wide descriptions of geology, soil types, topography, and groundwater conditions);
- Historical use sources (e.g., aerial photographs, Sanborn fire insurance maps, street directories, title information, and newspaper archives);
- Federal, state, tribal and local government records or databases; and other environmental record sources as available (e.g., prior investigation reports, hazardous material and waste inventories, spill records, permits, etc.)

The detail and scope of the Phase I report depends in part on the needs of the requesting party as well as the experience of the preparer. The type and usefulness of information available for a property will vary. Information is more likely to be readily available for urban areas in comparison to rural areas, and for post-1970 time periods in comparison to earlier periods. Preparation of an adequate Phase I report is likely to require significantly more information than available in HEER Office public files for the property.

For example, site investigation scoping for identification of a suspected pesticide mixing area and other former agricultural operations at high risk for contamination might include the following elements:

- Review of historical Sanborn fire insurance maps (see Figure 3-2) produced between late 1800s to 1970s, available at UH-Manoa library and other sources;
- Review of historical aerial photos (for example, R.M. Towill Corp collection) (see Figure 3-3);
- Review of archives for former sugar plantations (for example, UH-Manoa library and Hawaiʻi Agricultural Research Center);
- Interviews with people who worked at the facility or are otherwise familiar with the area;
- Inspection and photo documentation of identified, suspect sites.

Refer to TGM Section 9 for more information on pesticide mixing areas and former agricultural operations.

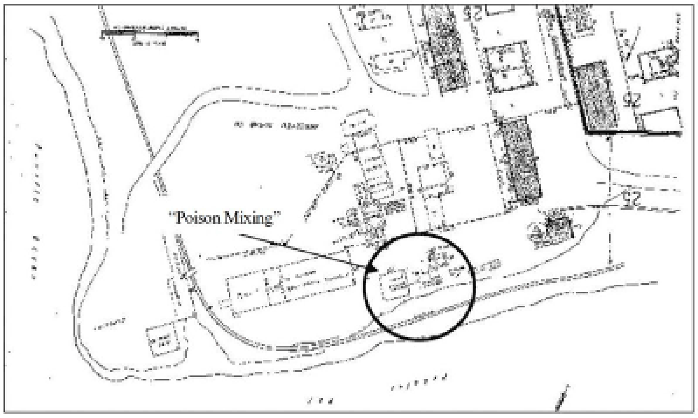

Figure 3-2. Portion of Sanborn Fire Insurance Map of Former Sugar Mill Operation Location of "Poison Mixing" area is identified, indicating potential pesticide contamination (e.g. arsenic). Sugarcane seed dipping vats generally are not indicated, which may have potential mercury or other fungicide contamination.

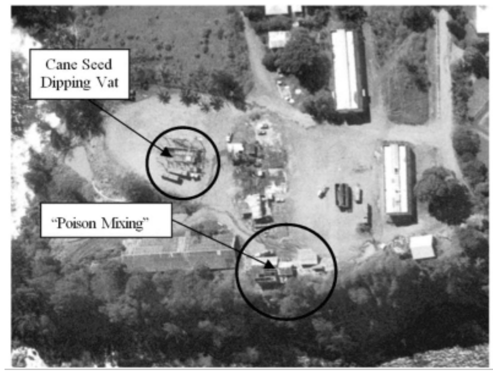

Figure 3-3. Historical Aerial Photo of Former Sugar Mill Operation Location of pesticide mixing area is identified as well as a sugarcane seed dipping vat. This is the same former sugar mill operation as shown in Figure 3-2.

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3.1.2 CONSULT WITH STAKEHOLDERS

Stakeholders are individuals or organizations who are affected by, who can affect, or who otherwise have interest, in the site (e.g., current and past owners, operators and employees; government agencies; nearby residents; developers; lenders; etc.). Stakeholders can be a valuable source of site information. For example, current or former employees can help document historical uses of the property, including locations of hazardous substance storage and disposal areas and point out other potentially important site features.

It is critical to consult with stakeholders early in the investigation scoping process to aid in an understanding of site issues. Early consultation with stakeholders, especially with the HEER Office, will help ensure that information collected during this stage of the environmental assessment process is sufficient to proceed to next steps. Avoidance of limitations on future use of the site should also be considered, for example by remediation of contaminated areas to meet unrestricted land use cleanup levels even though the property is currently used for commercial purposes (refer to HDOH, 2016).

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3.1.3 DEVELOP THE OVERALL SITE INVESTIGATION APPROACH

The overall site investigation approach is broadly defined and progressively developed during the initial scoping stage of the assessment process. This can include a compilation of chemicals of potential concern, potential environmental hazards posed by the chemicals, the locations and types of media to be sampled and the general analyses to be performed.

Developing a general idea of the investigation approach facilitates systematic planning. Ultimately a more refined approach is developed and incorporated into the Sampling and Analysis Plan.

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3.2 SYSTEMATIC PLANNING OF SITE INVESTIGATION

Environmental data must be of the appropriate type, quantity and quality to manage uncertainty and reach a defensible decision on appropriate response actions. The HEER Office recommends that the site investigation be developed using a **systematic planning approach** to ensure that data obtained during a site investigation are adequate to identify or negate the presence of potential environmental hazards. This approach emphasizes using straightforward, clear questions to design and guide the site investigation.

Systematic planning involves a series of well-thought-out steps that help ensure investigation results are adequate to characterize potential environmental hazards posed by contamination and provide sufficient information to develop response actions (refer to Figure 3-1). For the purposes of this guidance, these steps are summarized as follows (Figure 3-4):

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STEP 1 – State the Problem: Draft a Conceptual Site Model (CSM)	
Activities • Assemble, review, and evaluate existing data (e.g. Phase 1 ESA, other) • Develop a preliminary CSM	Outputs • Concise description of documented or potential contaminant issues on site • Initial CSM
STEP 2 – Identify the Objectives and Chemicals of Potential Concern (COPCs)	
Activities • Identify questions to be answered • Identify site characteristics • Identify COPCs • Identify potential outcomes	Outputs • Questions to be answered • General description of the site • List of COPCs • List of potential outcomes
STEP 3 – Identify Data Information Needs	
Activities • Identify existing valid environmental data • Perform a data gaps analysis	Outputs • List of types of information to be collected, and potential sources

• Identify additional types and sources of information needed • Identify media of concern • Identify potential environmental hazards posed by COPCs • Identify sampling approach and lab methods to be used • Specify contaminant(s) to be measured and action level to be used for making the decision	• Description of media and environmental hazards of concern • Sampling approach and analytical methods to be used • Table including target contaminants, primary environmental hazard, lab analytical method and reporting limits, and applicable HDOH EALs
STEP 4 – Define Decision Units (DU)	
Activities	Outputs
• Define the geographic boundaries of the area of interest • Identify temporal issues/sampling components for groundwater or ecological risk evaluations • Specify DU type, size, location, and shape (includes depth of soil DUs) • Identify particle size of interest and if surface organic matter will be sampled (for soil investigations) • Identify practical constraints (resources, accessibility, etc.)	• Definition of the project boundaries • Description and rationale for selection of Dus • Description of soil particle size to be collected and if leaves, roots and other surface organic matter should or should not be included in the samples • Description of constraints on selection and investigation of DUs
STEP 5 – Develop Decision Statement(s)	
Activities	Outputs
• Develop a detailed “if… then…if not..” decision statement(s) • Determine statistical test and confidence level to be used	• A detailed “if… then…if not…” decision statement regarding the parameter, based on the action level • Description of the statistical test and confidence level for data analyses
STEP 6 – Develop and Implement the Sampling and Analysis Plan	
Activities	Outputs
• Summarize site background • Specify investigation objectives • Identify scope of work	• Sampling and analysis plan • Work assignments and schedules • Tools / equipment list • Quality assurance project plan

• Specify sampling and analysis methods and tools • Develop work plan and schedule	• Safety and health plan • Sample collection documentation
STEP 7 – Assess Data Quality	
Activities • Validate and determine adequacy of site data • Statistical evaluation of data • Interpret data and draw conclusions • Identify data gaps	Outputs • Data validation evaluation • Determination if data met DQO • Data tables, summary, and maps
STEP 8 – Identify Potential Environmental Hazards	
Activities • Compare site data to HDOH Tier 1 EALs (or approved, equivalent action levels) • Identify specific, potential environmental hazards if Tier 1 EAL for target contaminant exceeded.	Outputs • Site Investigation Report • Environmental Hazard Evaluation report (separate report or included with other reports as appropriate)
STEP 9 – Refine the CSM and Recommend Further Actions	
Activities • Review site conditions, data collected, and environmental hazards • Identify additional site investigation actions needed • Assess Removal or Remediation alternatives for contaminants above Action Levels • Develop engineering or administrative controls for contaminants remaining on site	Outputs • Final CSM • Recommend additional site investigation actions (if needed) • Recommend advanced evaluation of identified environmental hazards (if needed) • Develop Draft Removal or Remediation Action Plans, as appropriate • Develop EHMP if contaminants above Action Limits will remain on site

Figure 3-4. Nine Steps of the Systematic Planning Approach

Steps 1 through 3 identify the objectives of the site investigation and establish the type of information needed to determine if contamination at the site poses unacceptable environmental hazards. Site investigation activities are developed and carried out in Steps 4 through 6. Information gained from the investigation is evaluated and summarized in Steps 7 through 9.

The steps above are similar to the concept of *Data Quality Objectives* (DQOs) published in some guidance documents (Robbat, 1997, USEPA, 2000; USEPA, 2001; Tindall, 2006; USEPA, 2006; Triad, 2007). This term is retained for use in this Manual. Early DQO guidance focused on data quality needs with respect to laboratory analysis performance, however, rather than the quality of the data in terms of field representativeness. The DQO steps are modified and expanded in this guidance in order to incorporate the concepts of “decision units” and the collection of representative samples at the beginning of the process. This more comprehensively reflects the typical progression of environmental investigations at sites with contaminated soil and groundwater.

Preparing DQOs prior to the initiation of field activities should be an essential part of all site investigations. Decision Units and Decision Statements are established up front to reflect the desired end use of the data. The data quality assessment is carried out to determine if the DQOs have been met. This process is essential to ensure that the objectives of the site investigation are well thought out and that all samples to be collected are tied to clear decision statements. This will help avoid debate over interpretation of the resulting data and minimize the collection of data that are unnecessary or unreliable.

The level of detail needed to adequately incorporate the systematic planning approach into a site investigation, as well as formal report preparation and submittal requirements, will vary from site to site. Many of these steps may be combined at relatively simple sites where the risk to public health is low and the extent of environmental impacts well confined. This will allow cleanup actions to be conducted quickly and effectively. A more formal review process with greater regulatory oversight will be required for larger or more complex sites where there is greater public health risk or environmental impact, significant public interest, or where site investigation and response activities will be drawn out over a long time period.

Each of the steps noted above are discussed in more detail in the remainder of this Section.

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3.2.1 OVERVIEW OF SYSTEMATIC PLANNING STEPS

A **systematic planning approach** is recommended to ensure that data collected during the site investigation are of the type and quality needed to meet the overall site assessment objectives. The nine-step systematic planning approach recommended by HDOH was summarized in the previous subsection. Additional detail is provided below and in Subsections 3.3 through 3.9 (refer also to Figure 3-1).

Step 1—State the Problem – Draft a Conceptual Site Model (CSM)

Summarize past or ongoing activities at the site that could have led to environmental contamination and will require additional investigation. Phase 1 Environmental Site Assessment documents are a good example of the type and level of detail useful to help summarize past and/or ongoing site activities. Summary information is then framed in terms of a CSM. The CSM is a comprehensive representation of the current understanding of site environmental conditions with respect to recognized or potential environmental hazards and is a necessary part of an Environmental Hazard Evaluation (See Section 13).

The CSM serves to summarize the current understanding of a site and identify gaps where additional data are needed. This then forms the basis of the site investigation. A detailed discussion of CSMs is provided in Subsection 3.3. The CSM is maintained and updated throughout the project as new data and information are obtained. To begin developing the CSM, a concise description of the site and potential problem(s) to be studied is prepared.

Issues to consider in Step 1 include:

1. What types of past or ongoing activities at the site could have led to environmental contamination?
2. What environmental conditions are identified in Phase I Environmental Site Assessment Reports (Recognized Environmental Conditions, including identified spill areas, storage areas, underground storage tanks, etc.)?
3. Can other sources of geologic or hydrologic conditions relevant to the site be identified (e.g. geotechnical reports, borings, etc.)?
4. Do preliminary data indicate the presence of contaminants in soil, groundwater or other environmental media greater than the HDOH Tier 1 Environmental Action Levels (EALs), and therefore the presence of potential environmental hazards?
5. Are data available from similar sites that may be useful for evaluating the site?
6. What are the regulatory requirements for reporting and investigating suspected releases of hazardous substances at the site?

Step 2—Identify the Objectives and Chemicals of Potential Concern (COPCs)

The primary objective of the Site Investigation is to collect data necessary to understand the presence and nature of potential environmental hazards at a site (e.g., direct exposure, vapor intrusion, leaching to groundwater, etc.). The site investigation must be designed to meet this objective, as well as to provide any additional information necessary to develop a response action to mitigate confirmed environmental hazards.

A list of site-specific questions is developed based on the initial CSM. These questions are framed so that their answers will be clear. Examples of typical site investigation questions are:

- Is soil in the vicinity of the former pesticide storage area contaminated above EALs over an area large enough to pose an environmental hazard?
- Does lead contamination in soil pose a direct exposure risk to residents?
- Is the size of the benzene plume in groundwater increasing, stable or shrinking?
- Does the contamination at the site extend beyond the property boundaries?

At this stage, questions are not specific enough to use in designing the sampling plan, but they roughly outline concerns at the site.

Potential outcomes – actions to be taken based on answers to the questions – should be identified. For example, if the question is “Does the mean concentration of lead in the DU surface soil exceed the action level?”, then potential outcomes of the investigation might be: (1) Yes; additional cleanup is needed; (2) No; no further actions are needed.

Issues to review and consider in Step 2 include:

- What are the important geologic and hydrologic characteristics of the site and adjacent areas?
- What existing surface and subsurface structures occupy the site?
- Are there sensitive ecological habitats on the site, or nearby?
- What areas of the site may require additional investigation?
- What COPCs may be in each area?
- What is the appropriate size and location of DUs for the site?

Steps involved in addressing these issues initially include:

- Identify known or potential sources of chemical releases, including underground and aboveground tanks, piping networks, storage areas, disposal areas, etc.
- Complete an initial, screening level evaluation of potential environmental hazards and determine the need for additional site data.
- Develop a description of general surface and subsurface characteristics, including paved versus unpaved areas, soil type, presence of debris or fill material, location of utilities, depth to and use of groundwater, location and types of other manmade structures, etc.
- Identify nearby water supply wells, bodies of surface water and other potentially sensitive ecological habitats that could be threatened by the contamination.

The following actions may also apply:

- Collect data necessary to evaluate emergency response actions.
- Identify short-term containment and/or stabilization issues that may be immediately necessary to prevent exposure of on-site receptors to contaminants and to prevent the off-site migration of contaminants while response actions are being evaluated.
- Identify data necessary to evaluate the ecological impacts of the contaminants.
- Identify potential spill areas and/or exposure areas for detailed characterization.

The target COPCs should be identified early in the process based on the known or suspected past history of the site and be specific to the site under investigations. The list of target chemicals will likely be narrowed down substantially prior to investigation based on the Phase I review of the site history and other pertinent information. Testing for lengthy, multiple suites of contaminants is rarely required.

The rationale for including a chemical as a COPC should be clearly stated. A chemical should not be listed as a COPC simply because it is included in a default suite of chemicals reported for a specific laboratory method. For example, if lead and arsenic are target COPCs for a site due to historical operations then they should be specifically referenced, rather than listing the full “RCRA

8" suite of metals typically reported by the laboratory (i.e.., arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver). This helps to ensure that the rationale for the selection of target COPCs is clearly discussed and minimizes the use of resources on unnecessary testing. Section 9 provides supplemental guidance regarding the selection of COPCs for several specific types of releases. Refer also to common contaminants listed in the HDOH Tier 1 EAL lookup tables found in *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH, 2016).

Step 3—Identify Data Needs

Understanding and collecting the information needed to answer the questions posed in Steps 1 and 2 is a critical part of the site investigation process. Data gaps are identified by an evaluation of existing site data and a determination of the need for additional data to meet site investigation objectives. Additional data may be needed for site characterization, health and safety planning, advanced evaluation of potential environmental hazards (e.g., need for a detailed, human health risk assessment) and the development of remedial alternatives (refer to Section 13). If additional data are needed, the intended use of the data should be clearly identified. Data needs should be continually re-evaluated and refined as more information about the site is gained and potential environmental hazards are identified.

Step 3 involves considering chemicals of potential concern and pathways that need to be investigated to determine the following:

- Can some groups of COPCs be eliminated from further consideration and testing based on data from previous investigations?
- What are the potential environmental hazards posed by targeted COPCs?
- What types of media should be collected and analyzed (e.g., soil, soil gas, groundwater, surface water, etc.) based on areas and types of potential contamination?
- For groundwater, how often will sampling need to be repeated, and how will samples for specific contaminants be collected/analyzed (e.g. total and/or dissolved metals)?
- How can representative concentrations of contaminants be best determined (e.g. Multi Increment sampling)?
- Will surface soil DU-MIS samples suffice, or will sub-surface DU-MIS soil samples be required as well?
- Will additional, non-traditional data potentially be needed to support the Environmental Hazard Evaluation or response action based on the results of initial data collected (e.g., bioaccessible arsenic data, batch test leaching data)?

Identify the optimal laboratory analytical method for the target COPCs and the media to be tested. Issues to consider in selecting lab analytical methods include:

- Is more than one laboratory method available for a target group of chemicals?

- If more than one lab method is available, is one method considered more accurate for the target COPC?
- Are reporting limits for each method sufficiently low to meet Tier 1 EALs for the COPC and, if not, are they within the generally acceptable range for commercial laboratories?
- Is prescreening using field equipment or a less rigorous lab method desirable to help refine the final analytical method? (refer to Section 8)

Samples collected during a site investigation may need to be split and sent to several laboratories for testing, based on the types of analyses required. All laboratories should have adequate internal QA/QC procedures to ensure sufficient data quality to satisfy the requirements of the DQO. Also, consider laboratory certification credentials during the lab selection process.

Less sensitive laboratory analytical methods may be necessary for samples that are known or suspected to be heavily contaminated. For example, Method 8280 (or equivalent) is considered to be adequate for testing of dioxins in soil. Testing of soil using an ultrasensitive, trace analysis test such as Method 8290 is not generally required to achieve reporting limits adequate for comparison to HDOH action levels (refer to Section 9). This will help avoid damage to laboratory equipment due to testing of highly contaminated samples.

Field screening may also be used as a screening tool to guide site investigations, but it is generally not acceptable to document the absence of contaminants. Examples of field screening equipment include photo ionization detectors (PIDs), flame ionization detectors (FIDs), and portable X-Ray Fluorescence (XRF) instruments. Additional information on use of field screening methods is provided in Section 8.

Data collected for targeted COPCs should be compared to action levels specific to the media tested. This is one of the primary uses of the HDOH Tier 1 Environmental Action Levels (Tier 1 EALs, refer also to Step 7). Use of the Tier 1 EALs is discussed in more detail in Section 13. Note that the HDOH EALs, as well as USEPA Regional Screening Levels (USEPA, 2014) and similar criteria, are not intended for comparison to individual, discrete sample data. The EALs instead are to be applied to the mean contaminant concentration within the targeted, decision unit.

In general, contaminants in soil, water, soil gas or indoor air at concentrations below the Tier 1 EALs do not pose a significant threat to human health and the environment. The presence of contaminants above the Tier 1 EALs does not necessarily indicate that significant environmental hazards exist, only that additional evaluation is warranted. Incorporation of the Tier 1 EALs in the site investigation work plan provides a useful endpoint for those tasked to carry out the fieldwork, and can reduce the need for remobilization and additional data collection.

The use of alternative action levels to help define the extent of contamination that may be of potential concern is acceptable but should be approved by the HEER Office in advance of the site investigation, or as part of a follow-up, site-specific Environmental Hazard Evaluation. Site-specific action levels must comprehensively address all potential environmental hazards posed by the chemical. Comparison to action levels that focus on a single potential concern, such as the USEPA Regional Screening Levels (RSLs) for direct-exposure (USEPA, 2014), may not be adequate. The presence of other potential hazards such as leaching, vapor intrusion, gross contamination and ecotoxicity concerns must also be evaluated using additional action levels specific to each hazard. As discussed in Section 13, action levels for each of these environmental hazards are incorporated into the HDOH Tier 1 EALs. Unlike the USEPA RSLs, this allows the HDOH EALs to be used as a stand-alone screening tool at most sites.

Environmental hazards that could be posed by targeted COPCs should ultimately be reflected in the Sampling and Analysis Plan. For example, a potential environmental hazard posed by volatile chemicals is the intrusion of vapors into existing or future buildings. The need to collect soil gas data should be evaluated at sites where releases of volatile contaminants have occurred. If heavy contamination is suspected or has been identified at a site, it may be prudent to include the collection of soil gas samples.

Concurrent collection of groundwater data should be considered at sites where soils are grossly contaminated with highly mobile contaminants (e.g., gasoline) or the type of contaminants present could otherwise pose significant leaching and groundwater contamination hazards (e.g., herbicides, such as atrazine). In other cases, additional laboratory tests may be run on split samples to better evaluate a specific hazard that is identified in initial site data.

Examples include:

- Collection of soil gas data at sites where initial soil and/or groundwater data indicate potential vapor intrusion hazards.
- Analysis of soil samples that exceed 24 milligrams per kilogram (mg/kg) total arsenic for bioaccessible arsenic in order to more closely evaluate potential direct-exposure hazards (see Section 9).
- Use of Synthetic Precipitation Leaching Procedure (SPLP) batch tests to better evaluate contaminant mobility in soil samples with reported concentrations of contaminants above action levels for leaching hazards. The SPLP batch test is used to evaluate the potential leaching of contaminants from soil under natural site conditions (refer to Section 13).
- Use of Toxicity Characteristic Leaching Procedure (TCLP) batch tests on contaminated soil that is to be disposed of in a landfill. The TCLP batch test uses more acidic conditions to simulate changing conditions over time in a landfill setting. TCLP data are used to determine if contaminated soil can be disposed of in a municipal landfill or instead must be sent to a permitted, hazardous waste landfill. Soil designated for disposal is considered to be a hazardous waste if TCLP data exceed regulatory limits found in HAR §11-261-24 and cannot be disposed of in a municipal landfill. (Note that soil is not generally considered to be a “waste” unless it has been excavated and a decision made for offsite disposal.)

A hazardous waste determination could require a separate sampling and analysis plan in order to address landfill disposal requirements (see Subsection 5.10). Contact the landfill for specific requirements. Consider the inclusion of additional sample collection and analysis in the original SAP in order address disposal needs prior to the initiation of site activities.

Step 4—Define the Decision Units

Steps 1-3 above will help to make a judgment call on how to best establish decision units (DUs) on the investigation site. A DU is a well-defined area of a site where a decision is to be made regarding the potential for contaminants to pose an environmental hazard, as defined in the HDOH Environmental Hazard Evaluation (EHE) guidance (HDOH, 2016). Put simply, a DU is the area and more specifically the volume of the targeted media (e.g., soil, sediment or water) that would be collected and analyzed as a single unit if possible. This is rarely if ever feasible and a representative sample (or samples) of the targeted media must instead be collected and submitted to a laboratory for analysis. In some cases, an entire site can be defined as a single decision unit; however, it is more typical to divide a site into multiple decision units based on known or suspected spill areas or areas where workers or residents are exposed to soil on a regular basis. A more detailed discussion of the selection of decision units is provided in Subsection 3.4.

The size and shape of a decision unit will depend on the specific, potential environmental hazards posed by the target COPCs, the intended use of the site and proposed response actions. Known or suspected spill areas should in general be treated as individual decision units. Spill area DUs are typically very small, ranging from a few hundred square feet to a few thousand square feet in area. This is especially important if the target contaminant is highly leachable from the soil and could pose a threat to groundwater resources or is highly volatile and could pose potential vapor intrusion hazards for buildings (e.g., water-soluble pesticides, solvents, light-end petroleum fuels, etc.). For relatively non-mobile contaminants the driving environmental hazard is often direct exposure, rather than leaching and groundwater protection (e.g., arsenic, lead, PCBs, polychlorinated dibenzodioxins and polychlorinated dibenzofurans “dioxins”, etc.). If specific spill areas cannot be identified then the appropriate DU size is the current or anticipated exposure area(s) for the site, such as an entire residential yard or the outdoor work area(s) of a commercial or industrial site. Exposure area DUs typically cover areas of several thousand square feet but could be smaller or larger depending on site-specific circumstances.

Points to consider include:

- What are the primary environmental hazards posed by the target COPCs?
- How should the decision units be defined to evaluate these potential hazards and associated risks?
- Do the selected DUs provide sufficient coverage of targeted spill areas and/or exposure areas on the site?
- What is the optimal area and depth of the DUs to evaluate potential exposure, leaching, vapor intrusion and/or gross contamination concerns?
- What is the optimal area and depth of the DUs to optimize potential remedial actions?
- What soil particle size will be collected for analyses?

As discussed in Section 4, testing of a large number of points within a targeted DU (e.g., >30) is generally required to obtain a representative concentration of targeted COPCs for the DU as a whole.

Establishing DUs early in the investigation will also help integrate the field investigation with the evaluation of potential environmental hazards, as well as the preparation of site remedial action plans and long-term management plans. The designation of DUs and development of clear decision statements prior to the initiation of activities in the field is necessary for all investigations, including cases where discrete samples are collected.

Step 5—Develop decision statement(s)

Develop decision statements using sampling information identified in Step 3 and the decision unit boundaries defined in Step 4. Specify contaminants to be measured and action levels to be used for making the decision.

Decision statements are often phrased in the form:
IF the concentration of [chemical] for the targeted decision unit based on [Multi Increment sampling methods] and analyzed using [analytical method] exceeds [value] THEN [action necessary]. IF NOT, then [outcome].”

Such as:
IF the mean concentration of total lead in soil from DU #1, collected using Multi Increment sampling as per the Sampling and Analysis Plan (SAP) dated (day/month/year), and analyzed using USEPA SW-846 Method 6020, exceeds 200 mg/kg, THEN it will be concluded that the soil in DU #1 could pose a potential direct exposure hazard to residents and additional assessment or cleanup will be needed. IF NOT, then it will be concluded that the soil in DU #1 does not pose a potential hazard and no further action is needed.

Or

If the mean concentration of total arsenic in the soil in DU #1 exceeds the Tier 1 action level of 24 mg/kg, then an arsenic bioaccessibility test will be carried out on the soil. IF NOT, then it will be concluded that the soil in DU #1 does not pose a potential hazard and no further action is needed.

If the data on which the decision will be based consists of multiple values, then the statistic to be used for decision-making must be specified. The most commonly-used statistics are (see Subsection 4.2.5):

- The arithmetic mean contaminant concentration in the DU or
- The 95% Upper Confidence Level (UCL) of the mean.

Step 6—Develop and Implement the Sampling and Analysis Plan

The Sampling and Analysis Plan (SAP) should be designed to enable the investigation objectives to be achieved within acceptable uncertainty limits. Additional information on preparing a Sampling and Analysis Plan is provided in Subsection 3.6. A suggested format is provided in Section 18.

As described in Section 4, HDOH strongly encourages the use of Multi Increment and decision unit strategies to enhance sample representativeness in the investigation of contaminated soil (Jenkins et al. 2005; Ramsey and Hewitt, 2005). Field studies have demonstrated that error associated with discrete soil sample data can be significant, including underestimation of both the extent of contamination present and the mean contaminant concentration for a targeted area (e.g., HDOH, 2014). Multi Increment samples can significantly increase the representativeness of contaminant concentrations for targeted areas. Selection of decision units is discussed in Step 4, as well as in Subsection 3.4. A comparison of discrete versus Multi Increment soil sampling approaches is provided in Section 4. Soil sampling tools and techniques are discussed in Section 5.

Issues to consider in developing the SAP for soil, groundwater, soil gas and other targeted media include:

- How can sample collection be optimized to achieve site investigation objectives in a cost-effective manner?
- Should resources be focused on an investigation of a specific COPC or environmental hazard?
- Are adequate maps of the site available and if not what level of surveying or mapping will be required?
- Will rights of entry be required?
- Will utility clearance be required?
- Are geotechnical or other types of testing also necessary and if so can this be combined with the site investigation?
- How much total sample mass (of the designated maximum particle size, if soil) will be necessary to run all the COPC analyses planned?
- How many field replicates are required to determine overall representativeness of sample data and precision of estimated mean concentrations, given the targeted DUs and COPCs?
- Is the lab familiar with, and does it have protocols for representative laboratory sub-sampling of field samples (required for Multi Increment samples)?
- Should additional lab sub-sampling replicates be included to further examine the precision of the lab sub-sampling/lab analysis compared to the field replicate data?
- For soil, has the lab taken steps to reduce Fundamental Error by determining and using a digestion/analysis mass that is based on the maximum particle size in the sample (e.g., ten gram minimum subsample mass recommended for metals analyses of <2 mm particle size soil)?
- Have laboratory quality control criteria been met?
- How many soil gas samples are required to adequately assess potential vapor intrusion hazards?
- Is the collection of sorbent tube samples for TO-17 analysis required to test for long-chain hydrocarbons at petroleum release sites?
- Given the expected subsurface conditions, what is the minimal well size needed to collect the necessary amount of groundwater for sample analyses, given the site geology (e.g., micro-wells may not allow the collection of adequate sample volumes in tight soils)?

- What are the optimal tools for collecting samples for analyses by the methods identified in Step 3?
- Will field screening be carried out and if so, how will it be utilized and compared to laboratory data?
- Are the investigation areas accessible using the proposed tools and drilling equipment?

Soil and sediment sample collection methods are discussed in Sections 4 and 5. The collection of groundwater samples is discussed in Section 6. Soil gas and indoor air sampling is discussed in Section 7.

The reporting limit/practical quantitation limit (RL or PQL) a lab expects to achieve for a particular method generally should be low enough to determine if the analyte is present at or above the Tier 1 EALs or designated alternate value that meets the site investigation objectives. This will be a factor in selecting both the method(s) and the laboratory. If the reporting level achievable using standard laboratory methods is greater than the target action level then the reporting limit can be used for screening purposes (refer to Section 13 and EHE guidance, HDOH, 2016).

If soil/particulate samples are being collected and analyzed, the laboratory should be employing a representative laboratory sub-sampling procedure when processing the samples and preparing lab replicates (see Section 4). Such sub-sampling procedures include use of a sectoral splitter or hand Multi Increment sampling (USEPA, 2003b). Representative sub-sampling in the lab is generally considered the most important factor in reducing overall laboratory error.

After selecting analytical methods based on data needs, the next step is to specify the data quality performance and acceptance criteria the data will need to achieve. Uncertainty limits and performance data are developed in more detail in the Quality Assurance Project Plan (see Subsection 3.7). Both field and laboratory data quality considerations should be included in setting overall data quality and acceptance criteria. Providing limits on decision errors provides limits on the uncertainty in the data (USEPA, 2006b). Uncertainty limits are site-specific, and include considerations such as precision, accuracy, completeness, and comparability parameters.

Exceeding Tier 1 action levels for some contaminants may indicate a need for additional (contingent) analyses. For example, if total arsenic is found to be present in soil above 24 mg/kg then the laboratory should be asked to carry out or subcontract for bioaccessible arsenic tests on the sample or on selected samples if multiple samples were collected (see Section 9). If contaminants are detected in soil above action levels for leaching hazards and the soil is to be left in place, then the laboratory should be instructed to carry out a batch test (i.e. SPLP testing) on the samples to better evaluate contaminant mobility and the threat to groundwater. These possible outcomes should be identified in advance under Step 3 and contingencies made in the project budget to cover additional, potential laboratory costs, as appropriate.

It is important for the team tasked with preparing and carrying out the site investigation to visit the site prior to finalization of the *Sampling and Analysis Plan*. Final selection of decision units and collection of samples is dependent on a multitude of site-specific factors, including the location of buildings and other structures, the presence or absence of pavement, traffic, access, need for clearing prior to sample collection, suitability of tools to collect media targeted, etc.

An integral part of all SAPs is a site-specific Health and Safety Plan. The Health and Safety plan should be prepared and reviewed with field staff before initiating investigation activities at the site. Although the HEER Office will confirm that a SAP contains a site-specific Health and Safety Plan, workplace safety and health issues are under the jurisdiction of the Hawaiʻi Occupational Safety and Health Division (HIOSH). HIOSH should be contacted regarding any safety and health compliance or consultation matters.

Issues to consider in developing the Health and Safety Plan include:

- What hazards could the targeted contaminants of potential concern or other chemicals that may be present pose to field staff at the anticipated or potential concentrations in soil, soil gas and groundwater?
- What physical site conditions could pose hazards to field staff and what type of personal equipment is necessary to protect field staff (e.g., for heavy equipment, confined spaces, trip and fall hazards, etc.)?
- What other environmental factors could pose hazards to field staff (e.g., heat, sunburn, poisonous plants or insects, wild animals, etc.)

Once the SAP has been finalized and, if required, reviewed and approved by the HEER Office, the site investigation should be implemented. The HEER Office should be notified at least two weeks prior to commencement of field activities.

Issues to consider while implementing the SAP include:

- Has all necessary sampling equipment been gathered and mobilized?
- Have field team members been made aware of potential chemical, biological and physical hazards that they may encounter at the investigation site?
- Can the collection of samples be accomplished in the proposed, allotted time?
- Do unanticipated field conditions warrant a change in sample collection approaches or sample point locations?
- What modifications will be required for the SAP if a new spill area is discovered, or a new contaminant of concern is identified?
- Do reported or field-detected levels of contaminants warrant additional laboratory tests on the samples?
- Do apparent environmental hazards identified in the field warrant an expansion of the investigation area, the collection of additional types of data, or the use of alternative laboratory analytical tests?

Unforeseen events and conditions are common, so it is important to allow flexibility in fieldwork. Unexpected field conditions such as very hard soils or unexpected rocks, pavement or debris below sample point locations could necessitate the use of heavier equipment or an alternative sampling strategy (see Section 5). Interim findings may indicate a (contingent) need for additional analyses; these should be part of the SAP in case they are needed.

Staff tasked with carrying out the field investigation should have a basic understanding of the Environmental Hazard Evaluation process (Step 8; refer also to Section 13). This helps ensure that DUs appropriate for the targeted COPC are designated and ensure that the appropriate amount and type of sample data are collected during the investigation. Major variations from a HDOH approved SAP should be discussed with the HEER Office project manager prior to implementation.

Step 7—Assess Data Quality

Data Quality Assessment starts with the sampling design (Step 3) and is also closely linked with the follow-up site investigation planning steps (Steps 4 through 6). The key focus of the sampling design is to control heterogeneity. The sampling design must be representative (e.g., Multi Increment sampling for soil) and in most cases will include field replicates in order to determine if the data are adequately representative, as well as determine sample variance from the mean. Good professional judgment is essential when selecting decision units for the site investigation. After the environmental data are collected, the data must be validated in accordance with the Quality Assurance Project Plan (QAPP; see Subsection 3.7) to determine quality (e.g., precision, reliability, etc.) and for comparison to relevant EALs. This assessment will determine if the data are sufficient to answer DQOs and address decision statements (Step 5) with the desired level of confidence.

Issues to consider in data validation and data quality assessment include:

- Did we follow the SAP? Were there any mistakes?
- Was the lab able to complete all analyses?
- How will samples outside lab acceptance criteria be further evaluated or handled?
- If samples were split and analyzed by multiple labs, how do the results compare?
- Did the laboratory re-analyze or provide appropriate interpretation data for samples that did not meet the sub-sampling or analysis QC criteria?
- Do the data come from the right decision unit?
- Are the sample data acceptable based on the field and laboratory QC data and acceptance criteria?
- Is there sample bias due to bad sample handling, transport, preparation, etc.?
- Are field replicate data used to assess precision appropriate for the subject data set?
- Are lab replicate and other lab QC measures used to assess the precision and accuracy of laboratory samples appropriate for the subject data set?

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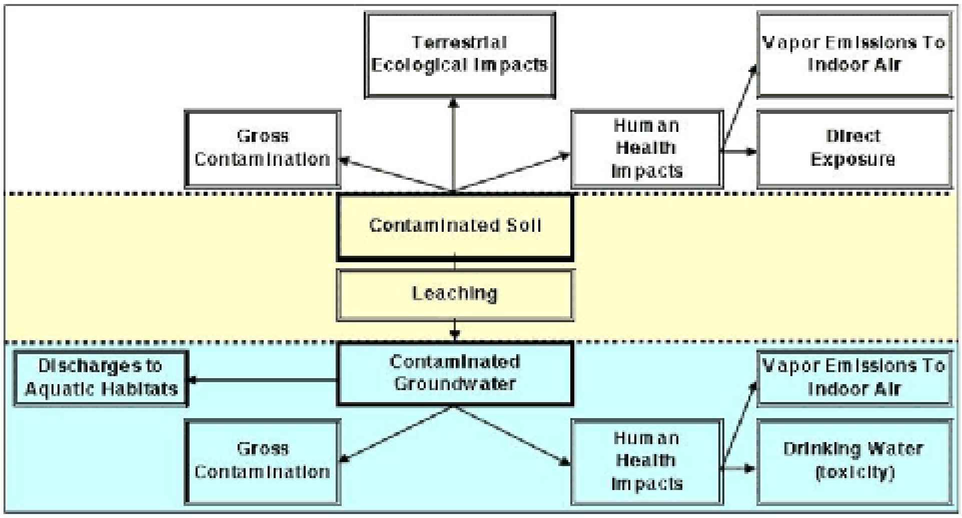

Figure 3-5. Summary of Environmental Hazards Considered in a Typical Environmental Hazard Evaluation

Additional detail on data validation and data quality assessment is provided in Subsections 3.7 and 3.8.

Step 8—Screen for Potential Environmental Hazards

Once the data assessment is complete, data judged appropriate for decision-making are compared to HDOH EALs to screen for potential environmental hazards or evaluated in a site-specific, Environmental Hazard Evaluation (see Section 13). The latter could include a site-specific, human health risk assessment although other potential environmental concerns must also be evaluated.

A summary of common environmental hazards posed by contaminated soil and groundwater is provided in Figure 3-5. Site investigations and Environmental Hazard Evaluations are iterative processes. Identifying potential hazards early on during site investigation activities, even at a cursory level, will help design and guide the progression of fieldwork and reduce the need for remobilization for additional sampling.

The default Conceptual Site Model used to develop the HDOH Tier 1 EALs assumes that each of these hazards could exist at a site given high enough contaminant concentrations and the absence of engineered or institutional controls. An evaluation of each of these potential environmental hazards must be considered in more site-specific Conceptual Site Models. Additional hazards may need to be considered on a site-by-site basis (e.g., uptake of contaminants in produce, etc.).

Issues to consider when screening for potential environmental hazards include:

- Do reported concentrations of target COPCS exceed Tier 1 EALs and indicate the presence of potential environmental hazards?
- Are additional data needed to fully define the horizontal and vertical extent of contamination exceeding Tier 1 EALs?

- What are the specific, potential environmental hazards posed by contaminants that exceed the Tier 1 EALs?
- Is additional testing of the samples needed to better evaluate potential environmental hazards (e.g., bioaccessible arsenic data or SPLP batch test data)?
- Are alternative laboratory analyses needed to better evaluate potential environmental hazards?

Issues to consider when interpreting the data and evaluating hazards include:

- Do current field conditions indicate an existing environmental hazard (e.g., exposed vs. capped areas of contaminated soil)?
- Could the removal of existing controls (e.g., pavement, buildings, site use, etc.) lead to actual environmental hazards?
- Is the collection of additional site data needed?

A basic understanding of the Environmental Hazard Evaluation by those tasked with carrying out the field investigation is critical to the accomplishment of the site investigation objectives. Field staff must ensure that the appropriate amount and type of sample data are collected during the investigation to allow completion of the Environmental Hazard Evaluation and formulate appropriate response actions. Current and anticipated (future) site conditions must be clearly documented and considered.

An overview of the Environmental Hazard Evaluation process and the use of Tier 1 EALs to screen site data for potential hazards is provided in Subsection 3.10 and Section 13. Use of the HDOH EAL Surfer to screen site data is strongly recommended.

Note that HDOH EALs are *not* intended for direct comparison to individual, discrete sample data. The EALs are intended for comparison to the *mean* concentration of a COPC in the target media (e.g., soil, air or water) over a specified area and volume of that media. The latter, referred to as the decision unit, is tied in part to the specific environmental hazard under investigation (Subsection 3.4; e.g., soil direct exposure area for evaluation of risk to human health).

Step 9—Refine the CSM and Provide Recommendations for Additional Actions

The CSM should be continually updated as site conditions and potential environmental hazards are better understood (refer to Subsection 3.3). The refined CSM should be used to identify data gaps and determine the scope of work needed to complete the site investigation.

Issues to consider when refining the CSM include:

- Do site conditions or sample data indicate the presence of previously unanticipated environmental hazards, or the absence of previously suspected hazards?
- Do reported concentrations of COPCs in soil present potential exposure hazards and warrant further analyses of the soil samples (e.g., direct exposure hazards for total arsenic and follow-up bioaccessible arsenic analysis; see Subsection 9.1.3.2)?

- Do reported concentrations of COPCs in soil present potential leaching hazards, indicating a need for soil leaching tests to evaluate contaminant mobility (HDOH, 2007, 2016) and/or the collection of groundwater data (Section 6)?
- Do reported concentrations of COPCs in soil or groundwater data present potential vapor intrusion concerns, indicating the need for soil gas or indoor air sampling data (Section 7)?
- Do reported levels of volatile COPCs in soil gas present potential explosive subsurface conditions, indicating the need for an expansion of the health and safety plan to address subsurface drilling or excavation activities?
- Do high levels of contaminants in groundwater indicate potential impacts to nearby aquatic habitats, suggesting the need to collect additional groundwater, sediment or surface water data?
- Do high levels of COPCs in soil and groundwater pose a threat to offsite migration which could lead to contamination of adjacent properties?

The revised CSM is used to make recommendations for additional actions necessary to complete the site investigation and direct appropriate response actions.

Additional site investigation may be necessary to fill identified data gaps, provide enhanced evaluation of specific environmental hazards, and develop clean-up or long-term management options, etc. Subsection 3.3 provides additional information about using CSMs to update and prepare site investigation plans.

Potential issues when considering additional site investigation actions include:

- Are the existing data adequate to address the objectives of the site investigation, as well as to prepare the Environmental Hazard Evaluation?
- Are additional data necessary for preparation of removal or remedial alternatives, or potential engineering or administrative controls?
- Do site conditions warrant emergency response actions to address conditions that pose an immediate endangerment to human or ecological receptors?

As discussed in the previous steps, site investigation is a dynamic and iterative process. Persons carrying out the site investigation should continually consult with those tasked with evaluating potential environmental hazards and those involved in developing response action plans. This will help to ensure that the additional data collected are adequate to fulfill the needs of subsequent stages of the project. Keeping these lines of communication open facilitates quick workplan changes when unexpected site conditions are discovered, reducing the need to remobilize field staff in the future and expediting completion of the project.

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3.3 CONCEPTUAL SITE MODELS

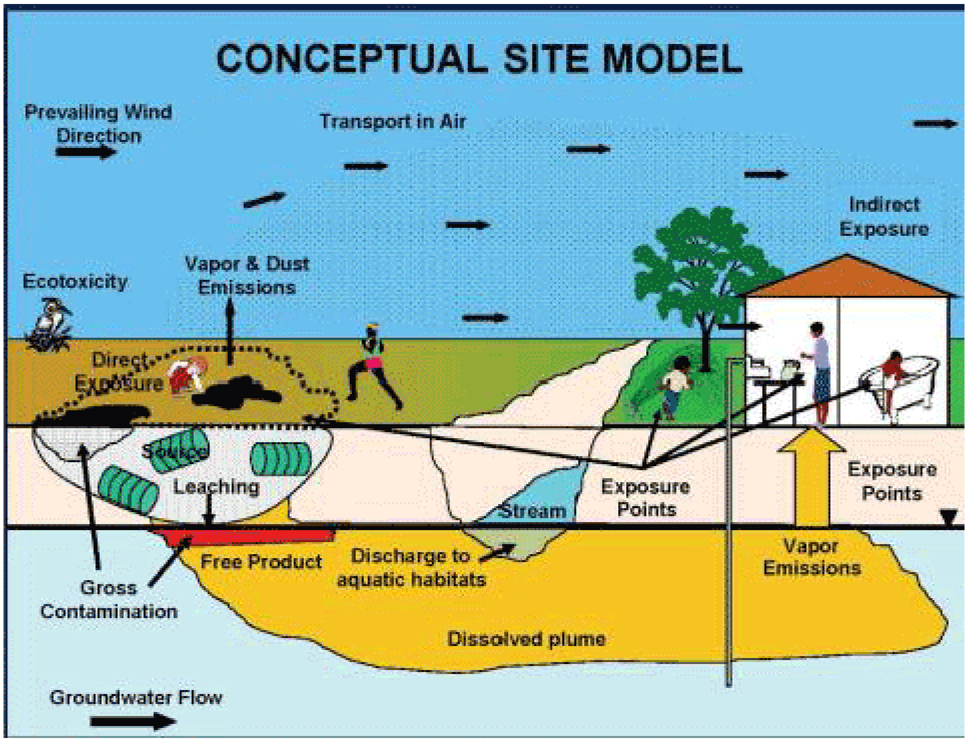

Figure 3-6. Pictorial Conceptual Site Model Depiction of common environmental hazards associated with contaminated soil and groundwater as well as potential exposure pathways for human and ecological receptors.

The CSM prepared during the first step of the systematic planning is a comprehensive representation of site environmental conditions with respect to recognized or potential environmental hazards. CSMs are also a necessary starting point for preparation of an Environmental Hazard Evaluation. The CSM is presented in a series of figures that depict current and future site conditions in three dimensions, with textual explanations of the figures, as needed. There are a number of ways to present a CSM. Figure 3-6 is a pictorial depiction of environmental hazards associated with contaminated soil and groundwater (see also Figure 3-5). Exposure pathways to human and ecological receptors are also indicated (e.g., incidental ingestion, dermal absorption, and inhalation). These types of depictions are useful for those not well versed in Environmental Hazard Evaluation or human health and ecological risk assessment. Additional examples of CSMs are presented in Section 13.

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3.3.1 SUMMARIZE KNOWN SITE CONDITIONS

The first step in the preparation of a CSM is to summarize current site conditions. At the most basic level, this includes a summary of the known or suspected extent and magnitude of soil and groundwater contamination. In addition, site conditions such as land use, groundwater use, potential onsite and offsite receptors, exposure or isolation of contaminated soil, etc., are identified, as are specific environmental hazards that may be posed by the identified contamination. The CSM is continually updated as the site investigation proceeds and site conditions are better understood.

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3.3.2 SCREEN FOR POTENTIAL ENVIRONMENTAL HAZARDS

A basic understanding of potential environmental hazards in terms of the environmental fate and transport of COPCs targeted for a site is important for development of a CSM and subsequent stages of an investigation. As discussed in Subsection 3.4, the designation of DUs is intricately tied to the type of environmental hazard(s) posed by the COPC. Common environmental hazards associated with contaminated soil and groundwater (Figures 3-5 and 3-6) include:

Contaminated Soil:

- Direct/indirect exposure to impacted soil (ingestion, dermal absorption, inhalation of vapors and dust in outdoor air);
- Emission of subsurface vapors to building interiors;
- Leaching and contamination of groundwater resources;
- Impacts to terrestrial habitats (terrestrial ecotoxicity);
- Gross contamination conditions (explosive subsurface vapor conditions, odors, general resource degradation, etc.);

Contaminated Groundwater:

- Contamination of drinking water resources (toxicity, taste and odors);
- Emission of subsurface vapors to building interiors;
- Discharges of contaminated groundwater to surface water aquatic habitats (aquatic ecotoxicity or gross contamination conditions);
- Gross contamination conditions (generation of explosive vapors from free product, odors, sheens, general resource degradation, etc.).

Additional environmental hazards also may require evaluation on a site-by-site basis (e.g., uptake of contaminants in produce, runoff of contaminated soil into surface water bodies, etc.). A more detailed discussion of these and other potential environmental hazards is provided later in this Section and in Section 13 (Environmental Hazard Evaluation), as well as the HEER Office document *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH 2016).

These environmental hazards form the basis of the default CSM used to develop the HDOH Tier 1 EALs. The applicability of each hazard for a given COPC should be reviewed on a site-by-site basis, depending on the nature of the contaminant (e.g., volatile vs. nonvolatile) and site characteristics (e.g., presence or absence of significant ecological habitat). For example, potential environmental hazards flagged based on a comparison of site data to HDOH EALs may in fact not be present under current site conditions but could pose a threat under future conditions (e.g., potential vapor intrusion hazards identified but no buildings currently on site; refer to Section 13 and HDOH 2016)

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3.3.3 DEFAULT CONCEPTUAL SITE MODELS

Located within 150m of surface water body or sensitive aquatic habitat?	Groundwater is a current or potential drinking water resource	Groundwater is NOT a current or potential drinking water resource
Yes	Default CSM A	Default CSM C
No	Default CSM B	Default CSM D

Figure 3-7. Four Default Conceptual Site Models Provided in the HDOH Tier 1 EALs

The HDOH Tier 1 EALs are based on an assumption that the environmental hazards noted above (as applicable to the specific contaminant) could exist at a site given adequately high contaminant concentrations within targeted DU areas and the absence of engineered or institutional controls (see Section 13). Four default CSMs or site scenarios are provided for in the Tier 1 EALs, depending on groundwater utility and location of a subject site with respect to nearby surface water bodies and aquatic habitats (Figure 3-7; HDOH 2016):

The default site scenarios reflect the basic CSMs used to develop and compile the Tier 1 EALs and serve as the starting point for preparation of an Environmental Hazard Evaluation (see Section 13). Only surface water bodies that are hydraulically connected to groundwater are considered to be potentially threatened by contaminated groundwater. This could include streams, drainage ways, or even leaky storm sewers that lead to a surface water body. Given their direct and potential rapid link to aquatic habitats, storm sewers in direct hydraulic connection with contaminated groundwater are considered to represent a “surface water body” for initial screening purposes. Measuring the piping invert in relation to the groundwater table at high-high tides and the presence or absence of free product at the discharge point of a storm drain can help determine if it serves as a pathway to a surface water body.

Data for a site are screened against Tier 1 EALs for the default CSMs most appropriate to the subject site. Preparation of a more site-specific CSM is not required, but may be useful or even necessary for sites with extensive contamination and/or significant public interest. One of the four default CSMs should, however, serve as the starting point for more site-specific CSMs. The default CSMs can also be depicted in a more classical “risk assessment” format, as presented for the default CSM in Figure 3-8.

Figure 3-8. Default Conceptual Site Model Default Conceptual Site Model used to develop Tier 1 EALs for sites that overlie a source of drinking water and are within 150m of a surface water body; assumes impacted soil exposed at surface.

Primary Sources	Primary Release Mechanism	Secondary Sources	[1]Potential Environmental Hazards		[2]Hazard Present Under Current or Future Site Conditions? Current	Future	Comments
ASTs, USTs, pipelines, drums, disposal areas, etc.	Spills, leaks, improper disposal	Soil	[3]Risk to Human Health	Direct Exposure	YES	YES	
				Vapor Intrusion into Buildings	YES	YES	
			[4]Risk to Terrestrial Ecological Habitats		YES	YES	
			[5]Leaching		YES	YES	
			[6]Gross Contamination		YES	YES	
		Groundwater	[7]Risk to Human Health	Direct Exposure	YES	YES	
				Vapor Intrusion into Buildings	YES	YES	
			[8]Risk to Aquatic Ecological Habitats		YES	YES	
			[9]Gross Contamination		YES	YES	

Notes (Figure 3-8):

1. Refer to Section 13 for discussion of specific environmental hazards. Tier 1, default conceptual site model can be modified on a site-by-site basis as needed.
2. All noted hazards assumed present or potentially present under current or future site conditions. Exposure pathways assumed complete for toxicity-related hazards.
3. Human health hazards include direct exposure to contaminated soil or vapors & dust from soil as well as the intrusion of vapors into overlying buildings.
4. Assumes a significant terrestrial, ecological habitat is impacted by the contamination with resulting toxicity to flora and fauna.
5. Assumes potential leaching of contaminants from soil and impacts to underlying groundwater.
6. Gross contamination hazards for soil include potential explosive hazards, odors, interference with construction work (e.g., soil reuse and disposal) and related concerns.
7. Human health hazards based on ingestion of contaminated groundwater as well as exposure via dermal absorption and vapors during showering and other water use.
8. Assumes discharge of contaminated groundwater into an aquatic habitat. Contaminants in groundwater screened using chronic, aquatic toxicity action levels for sites <150m from a surface water body (acute toxicity action levels applied if >150m from surface water body).
9. Gross contamination hazards for groundwater include potential taste & odors concerns for drinking water, presence of free product, explosive hazards, odors, sheens, interference with construction work (e.g., dewatering) and other related concerns.

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3.3.4 ADVANCED CONCEPTUAL SITE MODELS

The default CSMs used to develop the HDOH Tier 1 EALs are intentionally designed to be very conservative. The appropriate default CSM should be used to initially screen sites and, where appropriate, clear the site for unrestricted land use with minimal additional effort.

Site-specific CSMs can be prepared by modifying the default CSMs to more closely evaluate potential environmental hazards under current and anticipated future site conditions, as needed. A more detailed CSM is generally warranted at sites where cleanup costs could be significant, or at sites where long-term management of contaminated soil or groundwater will be required. A closer evaluation of current and future risks to human or ecological receptors will be particularly important. These types of CSMs will typically identify sources of contaminant releases, types of contaminated media, migration pathways, exposure pathways, and human and/or ecological receptors.

Figure 3-9. Expanded Conceptual Site Model

Primary Sources	Primary Release Mechanism	Secondary Sources	[1]Potential Environmental Hazards	[2]Hazard Present Under Current or Futur			

UST	Spills, leaks, improper disposal	Soil	[3]Risk to Human Health	Exposure Type	Secondary Release Mechanism	Exposure Route	
							On-Site Workers
							Current
							Future
				Direct Exposure	none	Ingestion	*No
							*No
						Dermal	*No
							*No
					Dust/ Vapors	Inhalation	*No
							*No
				[4]Vapor Intrusion into Buildings	Vapors	Inhalation	Yes
							Yes
			[5]Risk to Terrestrial Ecological Habitats	Current -No (no habitat or receptors)			
							Future –
			[6]Leaching	Current -Yes (soil in contact with groundwater)			
			[7]Gross Contamination	Current – Yes (potential explosive vapors)			
							Future – Yes
		Ground-water	[8]Risk to Human Health	Exposure Type	Secondary Release Mechanism	Exposure Route	
							On-Site Workers
							Current
							Future
				Direct Exposure	none	Ingestion	No
							No

						Dermal	No
							No
						Inhalation	No
							No
				[4]Vapor Intrusion into Buildings	Vapors	Inhalation;	Yes
							Yes
			[9]Risk to Aquatic Ecological Habitats	Current – *No (monitoring shows plume not migrat			
				Future – *No (monitoring			
			[10]Gross Contamination	Current – Yes (free product present)			
				Future – Yes			

Notes (Figure 3-9):

1. Summary of default environmental hazards to be initially evaluated at all contaminated sites.
2. Hazard evaluation results based on assumption that contaminated soil is capped with pavement and contaminated groundwater is not migrating (naturally or via storm sewers, dewatering, etc.). *Long-term management of contamination must be addressed in an *Environmental Hazard Management Plan* in the absence of cleanup.
3. Exposure pathways for daily workers not complete *provided site remains paved. Potential exposure of construction workers during future subsurface activities.
4. Recommend collection of soil gas data to further evaluate potential explosive hazards and vapor intrusion hazards.
5. No significant terrestrial, ecological habitat located on site or threatened by contamination.
6. Assumes contaminated soil is in direct contact with groundwater. Used to support collection of groundwater data for further evaluation.
7. Recommend remediation of gross contamination at a minimum to reduce vapor concerns.
8. Assumes groundwater is not used as a water supply and monitoring indicates that plume is not likely to migrate offsite under natural conditions.
9. Threat to aquatic habitats assumed insignificant *provided plume is not allowed to migrate offsite. Contaminants screened using acute, aquatic toxicity action levels.
10. Recommend removal of free product to extent practicable to reduce vapor concerns and continued source of contaminants to groundwater.

Figure 3-9 presents a more site-specific CSM for a hypothetical commercial/industrial site contaminated with petroleum. The CSM includes the following site assumptions:

- Contamination is restricted to the site boundaries;
- Area of contaminated soil is paved;

- Underlying groundwater is not a current or potential source of drinking water;
- Site is located more than 150m from the nearest surface water body.

A “Yes” in a cell under “Receptors” indicates that the noted exposure route is complete or potentially complete. This is important information for development of short-term or long-term response actions to address human health or ecological risk concerns.

The example CSM documents that the ingestion, dermal absorption and inhalation pathways for direct exposure to the contaminated soil are incomplete for daily on-site workers. Although the inhalation pathway could in theory still be complete, the presence of the pavement can reasonably be assumed to make this pathway insignificant. For construction workers, however, all of the direct-exposure pathways are considered complete because their work may involve removing pavement and disturbing contaminated soil.

The example CSM also indicates that the pathway for leaching of contaminants from soil and contamination of groundwater is complete, because contaminated soil is in direct contact with groundwater, even though the area is assumed to be capped with pavement. This is used to support the collection of groundwater data to more directly evaluate impacts and potential concerns. Removal of pavement could also exacerbate leaching and groundwater contamination due to infiltrating rain or irrigation water. This could require the maintenance of an impermeable cap over the contaminated soil under a long-term management plan prepared for the site (discussed below).

It is important to note that environmental response actions must identify and address all environmental hazards posed by a release, based on both current use and reasonably expected future use scenarios. In many cases, based on the current use of the site and the presence of existing engineered controls, an Environmental Hazard Evaluation might conclude that no current hazards exist (e.g., sites currently used for commercial purposes, with contaminated soil covered by existing buildings and pavements and no vapor intrusion concerns). Contaminant concentrations at the site could, however, indicate a potential hazard under land use scenarios that could lead to completed exposure pathways (e.g., redevelopment for residential use with open areas of exposed soil).

The more detailed CSM may be used to support a conclusion that contaminated soil and groundwater does not pose unacceptable environmental hazards under current site conditions. Depending on site conditions and planned uses, active remediation to eliminate future environmental hazards under any potential land use condition could be recommended or required. If active remediation is not practicable due to site conditions and/or financial constraints, the assumptions used in the CSM to support an absence of potential hazard under current site conditions can be used to develop an Environmental Hazard Management Plan (EHMP; Section 18; see also HDOH 2016). In the example, the EHMP would require that the area of contaminated soil remain capped, that a health and safety plan and soil and groundwater management measures be developed prior to any subsurface construction activities at the site, and that the need for long-term monitoring of groundwater be further evaluated. Actions related to restricted-use site closure, and the preparation of Environmental Hazard Management Plans, are discussed in more detail in Section 19.

A basic understanding of contaminant migration pathways and exposure pathways is necessary to formulate a CSM and guide site investigation and response actions, including preparation of an EHMP. Preparing and submitting a formal, detailed CSM, however, is generally only required at sites where significant contamination exists and cleanup and/or Environmental Hazard Management Plan activities are anticipated to take more than a year to complete.

Additional information on the development of CSMs is available in USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988) and USEPA's *Data Quality Objectives Process for Hazardous Waste Site Investigations* (USEPA, 2000). Note that examples of CSMs in these guidance documents often focus on human health or ecological risk assessment concerns and may not consider other potential environmental hazards, including leaching and potential contamination of groundwater (refer to Figure 3-5; see also Section 13). As discussed in Sections 2, 3 and 13, assessments of risk to human and ecological receptors are important parts of a more comprehensive Environmental Hazard Evaluation. Site-specific human health and ecological risk assessments do not replace Environmental Hazard Evaluations, however, and it is important to ensure that all potential hazards at a site are adequately evaluated.

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3.3.5 MAINTAINING AND UPDATING THE CONCEPTUAL SITE MODEL

The CSM should be maintained and updated as needed throughout the life of the site activities. As appropriate based on additional site information, refine the CSM to more accurately identify known or suspected sources of contamination, types and concentrations of contaminants detected at the site, potentially contaminated media, potential environmental hazards, potential exposure and migration pathways, potential human and environmental receptors, and related information.

Information that should be used to maintain and continuously update the CSM includes (along with other relevant information):

- Additional soil, soil vapor or groundwater data;
- Location of existing monitoring wells and past soil borings;
- Soil contamination summary figures with areas above EALs highlighted (preferably based on decision unit and Multi Increment sample data);
- Groundwater contamination summary figures with areas above EALs highlighted;
- Soil gas survey summary figures with areas above EALs highlighted;
- Direction of groundwater flow, depth to groundwater;
- Cross sections that depict the site stratigraphy as well as the lateral and vertical extent of contamination; etc.
- Identification of existing buildings, structures, infrastructure changes that might affect subsurface conditions or preferential pathways (e.g., addition of underground piping), roads,

surface water bodies, neighboring property operations and land uses, geographical features, etc.;

- Review of sources, exposure pathways, and potential receptors (see example in Figure 3-8);
- Advanced evaluations of specific environmental hazards.

Significant changes to the CSM may necessitate updates to decision statements (Step 5 of systematic planning), the sampling and analysis plan (Step 6 of systematic planning) and/or the Environmental Hazard Management Plan (see Section 19).

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3.4 SELECTION OF DECISION UNITS

A decision unit (DU) is an area where a decision is to be made regarding the extent and magnitude of contaminants with respect to potential environmental hazards and associated risks to human health and the environment, as described in Section 13. A DU is necessarily a volume as well as area of soil. Decision units are designated in terms of size and location in a manner that ensures the objectives of the site investigation will be accomplished.

An important goal of a site investigation is to estimate the mean concentration of a contaminant for a designated DU volume of soil. A DU can be thought of as "The entire volume of soil that you would send to a laboratory for testing if this was indeed possible." Tested as a single sample, the concentration of the contaminant reported by the laboratory would represent the true mean for the DU volume of soil as a whole. This is usually not feasible given the large volume of soil assigned to a DU. A representative sample or samples of the soil must instead be collected and tested. As discussed in Section 5 while this can in theory be accomplished using discrete samples, Multi Increment samples are far more reliable and ultimately more cost efficient.

The designation of DUs is, importantly, independent of the sampling method used to characterize the area targeted. Practitioners new to sampling theory and Multi Increment sampling methods (Subsection 4.2) are often concerned about potential "dilution" of contaminated areas "hot spots" in comparison to traditional, discrete soil sampling methods (refer to Subsection 4.3). This is addressed through the designation of well-thought-out DUs that establish the desired resolution of the investigation. Although not directly referred to, the concept of "DUs" was an inherent part of past, discrete soil sample investigations. Discrete soil sample collection points were typically designated based on a desire to characterize contamination in one area versus another. As discussed in the subsections below, the area intended to be represented by a single, discrete sample point (or cluster of sample points) is designated as a separate DU for characterization. A large-mass, Multi Increment sample is then collected from multiple (e.g., 30-75+) locations within this area rather than reliance on a small, discrete soil sample collected from a single location. The number of DUs designated for a particular investigation not coincidentally often corresponds with the number of discrete soil samples or clusters of samples that might have been collected under past approaches.

Decision units can be designated for characterization of surface soils and/or subsurface soils. Designation of DUs for surface soil is described in Subsections 3.4.2 and 3.4.3. Designation of

DUs for subsurface soils is discussed in Subsection 3.4.4.

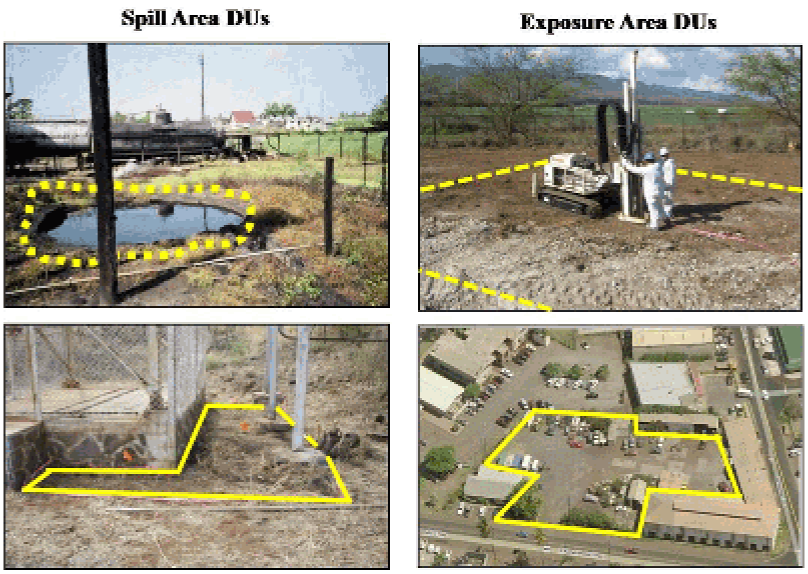

Figure 3-10. Example Spill Area and Exposure Area Decision Units

Establishing clear site investigation objectives and designating DUs to achieve these objectives early in the site investigation design helps develop an effective sampling approach to characterize a site. This ensures that adequate data are available to prepare an Environmental Hazard Evaluation (EHE, see Section 13), develop removal or remedial options, or carry out further investigation. A discussion of DU investigation strategies in the context of EHEs is also included in the HDOH guidance document *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH, 2016).

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3.4.1 DECISION UNIT DESIGNATION

The designation of DUs for characterization is unique to each site and depends in part on the specific type of environmental hazard under investigation (see Step 8 in Subsection 3.2 and Section 13). Decision units generally fall into two categories (Figure 3-10): 1) Spill Areas, and 2) Exposure Areas. As the name implies, a Spill Area DU represents a specific area where releases of hazardous substances are known or suspected.

Example Spill Area DUs might include former waste storage or disposal areas, the area (and volume) of contaminated soil under and around a leaking underground tank or an area of a site where contaminated fill material is suspected to have been placed. Identification and characterization of such areas is a common objective of an environmental investigation.

An Exposure Area DU is an area where receptors, human or ecological, routinely access and could be exposed to hazardous substances. Example Exposure Area DUs might include the yard of a residence or an unpaved area of exposed soil at a commercial or industrial facility. Exposure Area DUs might include isolated (unknown) spill areas, but as described below determination of the exact location of such areas is not required for assessment of potential direct-exposure risk, provided that the sample (or samples) collected from the DU is representative of mean contaminant concentration for the DU as a whole. Large Exposure Area DUs initially anticipated to be clean might be divided up into small DUs for re-characterization if they are found to be contaminated, in order to help optimize removal or remedial actions. The need for smaller decision units for future response actions should in general be considered up front, however, in order to minimize the time and cost required to resample an area.

The appropriate type, size, shape and number of DUs for a given project is necessarily site-specific and must take into consideration the historical, current and future use of the site. A strong understanding of the historical use of a site is critical to the designation of DUs (see Subsection 3.1.1). Historical site plans, insurance maps, historical aerial photos and discussions with past or current workers are very useful for determining initial DU areas. Obvious or suspected spill areas should normally be investigated as separate DUs. This includes structural remnants of potential hazardous substance storage or disposal areas, suspect pits and trenches, stained areas and low points where runoff could have collected.

Investigation objectives and approaches can vary over time as the project proceeds and alternate DUs may need to be established to assist in response actions or long-term management of sites. For example, DUs established for site characterization purposes may need to be refined for the removal or remedial phase of the project to better isolate high-priority areas and optimize resources available for cleanup.

When contamination poses multiple, potential environmental hazards then the smallest DU area and depth (i.e., highest resolution) should be selected to characterize the area. DUs for different media (e.g. soil vs. groundwater vs. soil gas vs. indoor air) should in most cases be treated separately, even if they are investigated concurrently. DUs for different media could overlap but may have different decisions associated with them.

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3.4.2 EXPOSURE AREA DECISION UNITS

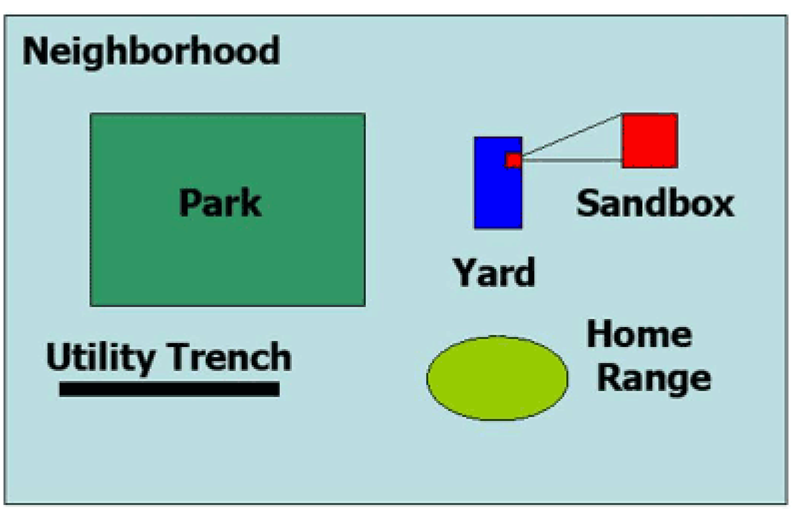

Figure 3-11. Example Exposure Area Decision Units Figure shows areas where residents or workers may be exposed to contaminants in soil on a regular basis. For ecological receptors, an example exposure area is the *home range*. The size & shape of exposure area decision units depends on the targeted receptor and the desired scale of the evaluation.

In the absence of a known or suspect spill area, the most appropriate Decision Unit for relatively immobile contaminants that primarily pose direct-exposure, toxicity-based hazards (e.g., lead, arsenic, dioxins, polychlorinated biphenyls [PCBs], polynuclear aromatic hydrocarbons [PAHs], etc.) is the assumed exposure area for the site receptor(s). "Exposure areas" are areas frequented by residents or workers or wildlife that may come in contact with contaminants in soil on a regular basis (see Section 13). Examples include residential yards, schoolyards, playgrounds, gardens, open areas on commercial/industrial properties, home range, etc. (refer to Figure 3-11). For exposure area DUs, the primary question is "What is the mean concentration of the target contaminant across the exposure area as a whole?" Exposure area DUs can be based on current land use (e.g., an open area of a commercial or industrial site) and/or future use of the area (e.g., proposed residential lots).

The top two to six inches of soil is generally considered for surface soil DUs, depending on the site-specific DQOs (USEPA 2011d; <CalEPA 2013). The top 0-6 or 0-4 inches of soil are commonly selected for surface soil Dus in Hawaiian Islands investigations. Exposure area DUs for residential properties typically encompass the entire yard, but could also focus on play areas or other areas of the yard that are frequented most. DUs for apartment complexes should focus on open common areas. For future redevelopment projects that involve single-family homes, the size of a hypothetical residential lot is generally assumed to be 5,000 ft² (see Subsection 3.5).

The location and size of exposure area DUs for commercial or industrial sites is necessarily site specific. DUs should be based on the location of exposed areas of soil and use of the site by workers. As a default and especially for undeveloped properties, exposure areas should be initially limited to half an acre or approximately 20,000 ft². When possible, designate DUs and investigate the site in a manner that allows future, unrestricted land use (i.e., residential land use, see Section 13). This will minimize the need for restrictions on future site use or delays in redevelopment.

Recall that soil EALs are *not* intended for direct comparison to individual, discrete sample data, although this may be useful for general screening purposes (refer to Step 8 in Subsection 3.2.1). The EALs are intended for comparison to the *mean* concentration of a contaminant in soil within the designated DU. Soil action levels for direct exposure risks, for example, are intended to address long-term, "chronic" exposure to very low concentrations of contaminants in soil. Exposure is assessed in terms of random exposure to contaminants in soil throughout the DU area over a period of many years (see Section 13).

It is not necessary and indeed not practical to attempt to identify the "maximum" and "minimum" concentration of a contaminant within the DU. If a contaminant is present, then at some, minute mass of soil the concentration of the contaminant will necessarily be 100%, or 1,000,000 mg/kg. It is also highly likely that the contaminant is entirely absent in scattered, small masses of soil within the same area. Estimation of the representative, mean concentration of a contaminant for a DU requires that a representative proportion of both higher and lower contaminant concentration areas be included in the sample data. As discussed in more detail in Section 4, this is best accomplished by the collection of a Multi Increment (versus discrete) sample from the DU. Replicate field samples are routinely collected from DUs to evaluate the precision of the original sample data.

Examples of DUs based on exposure areas are included in Subsection 3.5. Decision units based on exposure areas can also be established for ecological risk assessments. Additional guidance on decision units for ecological risk assessments will be included in the TGM in the future.

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3.4.3 SPILL AREA DECISION UNITS

For use in this guidance, a “spill area” is defined as a discernable area of elevated contamination in soil that can be mapped with respect to surrounding areas. Examples include areas with obviously contaminated and stained soils, unpaved areas used to store or mix hazardous chemicals, known waste disposal areas, areas immediately adjacent to transformer pads or other types of equipment that may have contained hazardous chemicals, releases from pipelines, etc.

The isolation and evaluation of individual spill areas is generally necessary to evaluate environmental hazards associated with soil leaching, vapor intrusion and gross contamination hazards (see Step 8 in Subsection 3.2 and Section 13). This applies to most releases of petroleum, solvents and highly mobile pesticides like atrazine and ametryn. In these cases, the appropriate question is “What is the mean concentration of the contaminant(s) within the volume of soil impacted by the spill”? Spill area DUs are sometimes recognizable based on surface staining but this is not always the case (e.g., PCP-related dioxins and arsenic). Typical spill area DUs are a few hundred to a few thousand feet in area and can extend to varying depths, depending on the nature of the contaminant released (see Subsection 3.5). For stockpiles, a default DU volume of twenty cubic yards is recommended for testing of soil stockpiles impacted by contaminants that could pose potential leaching concerns (HDOH 2011b).

If the target contaminant at the site poses leaching, vapor intrusion and gross contamination hazards, then the spill area should be designated as a separate DU for characterization. For example, a spill area associated with a petroleum release around an aboveground storage tank should be identified as a separate DU and appropriately investigated. This is because petroleum contamination can pose multiple environmental hazards, including leaching of contamination to subsurface groundwater resources, intrusion of vapors into overlying buildings and nuisance or even explosion hazards associated with grossly contaminated soil. It is inappropriate to incorporate data outside of the spill area in the evaluation of these types of hazards.

It may also become useful to identify and isolate small spill areas within a larger exposure area DU if the mean concentration of the target contaminant exceeds action levels and remediation is required. For example, isolating and remediating spill areas at a site heavily contaminated with arsenic can help optimize remedial actions to reduce average exposure concentrations (see Subsection 4.2.9 and 4.3.3). The cost-benefit of subdividing an initially larger DU into smaller DUs for additional, more detailed characterization is necessarily site-specific. The need for smaller DUs and a better resolution of contaminant distribution should ideally be taken into account as part of the initial designation of DUs at the site. Careful planning ahead of time will allow decisions to be made based on the original set of data collected and avoid the added time and expense of additional investigation.

Isolation and remediation of spill areas within an exposure area DU may also be necessary to prevent localized but heavily contaminated soil from being spread out across a larger area during future construction activities. For example, PCB-contaminated soil in the immediate vicinity of a transformer pad may not in itself pose direct exposure hazards to workers or even future residents given the assumed exposure area. However, under a future redevelopment scenario, the soil could be excavated and spread out over a much larger area. This could result in a dramatic increase in the average concentration of a contaminant across the DU(s). Decision units for these types of spill areas as well as other examples are described in Subsection 3.5.

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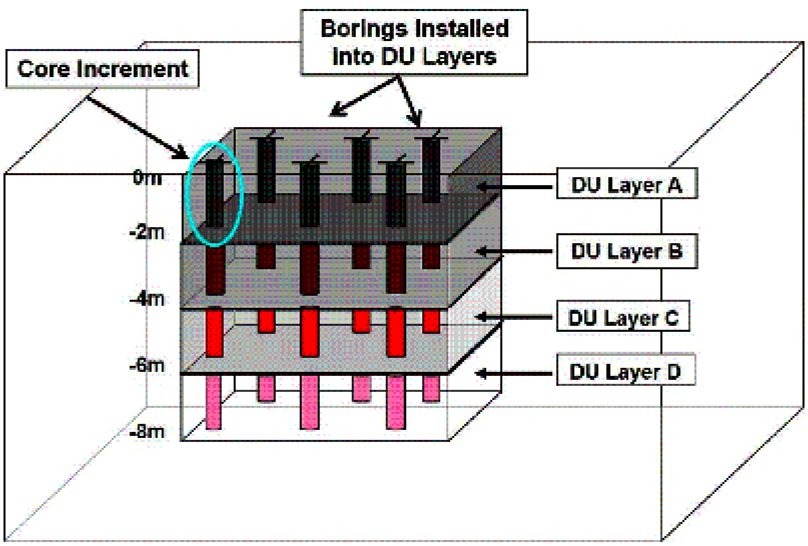

Figure 3-12. Designation of DU Layers for Characterization as Part of a Subsurface Investigation

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3.4.4 SUBSURFACE DECISION UNITS

A similar approach should be followed for designation of subsurface DUs (e.g., review of site history and initial field observations). An investigation of the vertical extent of contamination is typically required for releases of liquids or other chemicals that could migrate downwards and contaminate deeper soil or groundwater. A subsurface investigation may also be required to further delineate contamination documented at the surface, determine the depth of buried contamination, or the extent of contaminated fill material.

A small number (e.g., <30) of *Exploratory Borings* are usually advantageous during the initial stages of an investigation, similar to initial field inspections of surface soils to identify potential spill areas. The resulting information can be used to identify obviously contaminated intervals (e.g., visual observation of petroleum contamination, ash layers, elevated PID readings, etc.) and assist in designation of subsurface, DU Layers for more detailed characterization.

Designated depth intervals should be targeted for characterization, (Figure 3-12). A subsurface investigation of suspected deeper contamination might, for example, include DU layers designated from 0.5′-1.0′, 1.0′-2.0′; 2.0-5.0′ and 5.0-10′ below ground surface. This is necessarily site specific and dependent on the contaminants and objectives of the investigation. Subsurface DU Layers might, for example, be designated in a manner that allows optimal resolution of contaminant distribution and mass for *in situ* remedial actions. Subsurface DU layers might also be designated in a manner that allows for optimization of *ex situ* removal or remedial actions, including segregation of contaminated soil that may require expensive treatment or disposal from otherwise clean areas of soil. Refer to the examples provided later in this Section.

Subsurface DU layers are ideally characterized to the same level of detail as carried out for exposed, surface soil DU, with 30-50+ increments collected and combined to form a bulk, MI sample. This will require the installation of borings through the overlying soil to access the targeted layer below and/or the collection of samples from pits or trenches (see Section 5).

As discussed in Section 4, characterization of subsurface DU Layers using Multi Increment sampling approaches is recommended. The collection of discrete samples from targeted depth points in a core (e.g., every five feet) is unreliable for characterization of subsurface soils. This is due to potential, small-scale, random variability of contaminant concentrations in soil at the scale of a discrete sample and/or the subsample mass tested by the laboratory (see also Schumacher and Minnich, 2000, Feenstra, 2003, HDOH, 2014). In Figure 3-12, the section of the core extracted from a DU layer represents an “increment” under a Multi Increment sampling approach (refer to Section 4). Core increments extracted from targeted DU layers are normally subsampled and combined in the field to prepare bulk MI samples in order to reduce the total mass of soil submitted to the laboratory for processing and analysis.

The thickness of subsurface DUs could vary between boring locations. For example, it may be desirable to determine the mean concentration of lead in an irregular, subsurface layer of fill material or debris across a site. In one area the layer might be a few inches thick, while in other areas the layer might be several feet thick. The mass of soil collected from increments extracted from the layer should be weighted in order to collect a representative sample. This can be done by collecting a fixed mass of soil from a fixed spacing of soil plugs extracted from the core (e.g., five-gram subsamples collected every two inches).

For samples to be analyzed for VOCs, collect regularly spaced (for example every two to six inches) 5 gram plugs from the targeted core interval or DU layer and place them in a sampling container with methanol while in the field. If this option is not feasible (e.g., due to methanol shipping constraints), individual subsample plugs can be collected in small gas-tight coring devices (e.g. Core-N’-One® or Encore®-type containers) and immediately frozen for shipment to the laboratory (see Section 11). The laboratory should be instructed to combine the increments in methanol prior to extraction and analysis.

In some cases it may be desirable or otherwise necessary to use an individual borehole as a DU for decision making. The borehole itself can be a “DU” if this is the scale at which a decision will be made. For example, single boreholes might be used to determine the depth to the bottom of contaminated fill at specific locations within a site in order to assist in remedial plans (Figure 3-13). In other cases, obstructions and other site factors may limit the number of borings that can be installed at a site to estimate the lateral extent of contamination. Investigations of active gas stations with suspected, leaking underground storage tanks (USTs) or small USTs associated with boilers or generators are a common example (Figure 3-13). The installation of a number of borings adequate to collect proper MI samples at such sites (e.g., 30+) is often impractical. The objective of the investigation might instead be to simply determine the presence or absence of contamination at depth at a specific location within the facility. Limited sampling objectives such as these could be carried out with a smaller number of borings, especially for contaminants such as petroleum that are easily identifiable in the field.

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Figure 3-13. Example Gas Station and Former Boiler UST Sites Where Single Borehole DUs Might be Used.

These example sites show where single borehole DUs might be used for investigating the lateral and/or vertical extent of contamination. The hypothetical borehole locations are noted by red circles. This is adequate to determine presence or absence of the contaminant(s) only.

Data from a single or otherwise small number of borings will not be adequate to estimate the mean concentration of the contaminant in the area of the boring, but limited objectives for an investigation may be achieved. Narrow fingering of contamination into otherwise clean areas of soil could, however, cause the full extent of contamination to be underestimated. This approach is not reliable for contaminants and/or targeted contaminant layers that are not easily recognizable in the field. The use of Laser Induced Fluorescence or Membrane Interface Probe methods for near-continuous readings of subsurface conditions can assist in providing higher quality data (refer to Section 8).

The collection of traditional discrete samples from targeted depths within borings is strongly discouraged, again due to the potential for significant, small-scale variability and resulting "false negatives" and unreliability of data interpolation between sample points. Designation and testing of targeted, DU Layers are especially important if decisions are to be made on data from a single boring. This might include the interval observed or suspected to have the highest probability of being contaminated (e.g., staining, odors, field XRF, debris, etc.). Intervals below and above this zone would be designated as separate, “perimeter” DU Layers to verify anticipated clean soil (see following Section).

For example, Figure 3-14 depicts boring locations and DU Layers for a hypothetical gas station with both lead-contaminated fill material and a leaking underground storage tank. The fill material is marked by pieces of wire, melted glass, burned wood and a distinct lead signature using a field XRF. Soil contaminated by the leaking tank is marked by a distinct, gasoline odor, staining and elevated PID readings.

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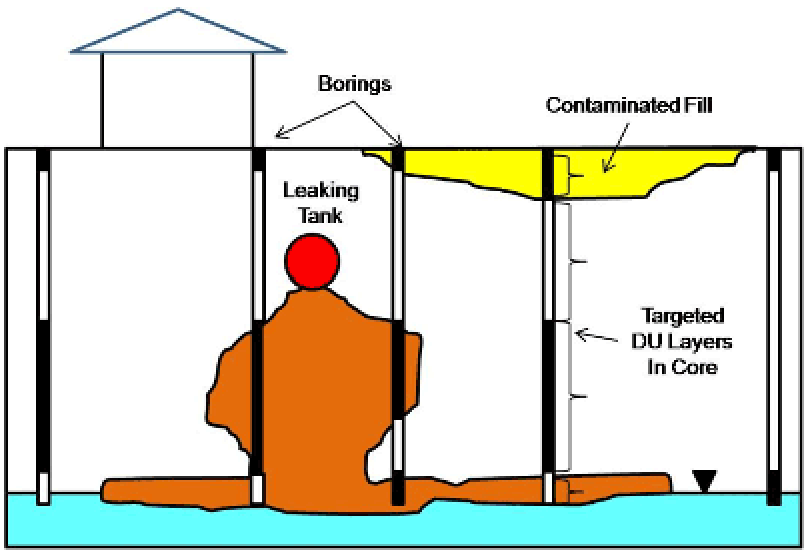

Figure 3-14. Use of a Single or Small Number of Boring DUs to Estimate the Vertical or Lateral Extent of Contamination at a Specific Location within a Site.

This method can be used with the entire targeted core interval or a representative subsample of the interval submitted to lab for processing and testing. Submitting the entire DU layer to the laboratory for processing and analysis is preferable, since this eliminates potential field error (see also Subsection 3.5.6). This is referred to as “direct inference” (AAFCO, 2015),

Borings are installed to estimate the lateral and vertical extent of contaminated soil associated with the two scenarios. Where encountered in a boring, intervals of fill material and/or gasoline-contaminated soil are designated as separate DU layers for characterization. The core in between these intervals is designated as a “perimeter” (or “confirmation”) DU layer and likewise targeted for characterization. Similar DU layers are designated outside of the apparent margins of contamination in order to confirm that the same interval of soil is now clean. For example, this might include testing of the upper two feet in borings to verify the absence of contaminated fill material, the interval of vadose-zone soils previously identified to be contaminated by the tank release and soil at capillary fringe zone at the water table. Including a core interval across the capillary fringe is especially useful, since this has the highest chance of catching the presence of contamination that has reached the water table (see Figure 3-14).

Such core intervals might be considered “discrete” samples in that they are to be independently processed and tested. Reference to the samples as “core intervals” is preferable, however. This will help to avoid confusion with traditional and less reliable “discrete” samples collected from a single depth point within a core.

The installation of a large enough number of borings to estimate the mean concentration of termiticides in soil under an existing building slab likewise may not be practical (e.g., Technical Chlordane or aldrin-dieldrin). In such cases the HEER Office recommends that soil be collected and combined from a minimum of three borings through the slab. The resulting bulk sample should be processed in the same manner as done for a traditional, MI sample and the presence or absence of termiticides noted. The reported concentration of termiticides in the soil should not be relied upon for final decision making purposes.

As discussed in Sections 4 and 5, if the volume of soil in a boring for a targeted interval is small enough (e.g.1-3kgs), then the entire interval should again be submitted to the laboratory for processing and testing in the same manner as carried out for MI samples. If soil is to be tested for volatile organic chemicals (e.g., TPHg and BTEX) then subsampling of the targeted interval in the field and placement in methanol or gas-tight individual containers will be required (see Section 5). Note that plugs of soil removed from the core are not “increments” in the sense of MI samples. They are instead subsamples of core increments. The spacing and number of plugs necessary to collect a representative subsample of the core increment will vary based on anticipated, small-scale heterogeneity of the target contaminant in the core as well as the total, desired mass of soil to be collected from the targeted DU layer as a whole. This is discussed in more detail in Section 5.

The use of limited borings to estimate the lateral and vertical extent of subsurface contamination can be very useful and cost-effective for design of initial remedial actions. A more detailed characterization will normally be required for final decision making purposes (unless preliminary data will already be used to assume a potential environmental hazard exists) or to confirm the effectiveness of cleanup actions.

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3.4.5 PERIMETER DECISION UNITS

“Perimeter DUs” are established immediately outside an area of suspected heavy contamination in order to confirm the lateral extent of contamination. Perimeter DUs can also be used to delineate the extent of contamination adjacent to any exposure area DU that has been found to exceed the applicable HDOH EALs. Soil contamination is typically delineated out to levels that fall below HDOH EALs, even if this involves crossing property borders (assuming property access is granted by the neighboring property owner). The number and design of perimeter DUs is necessarily site-specific and based in part on the confidence that the DUs will be placed in areas that are unlikely to be contaminated. For example, avoid letting a small area of contamination cause a much larger perimeter DU to fail action levels and require additional investigation.

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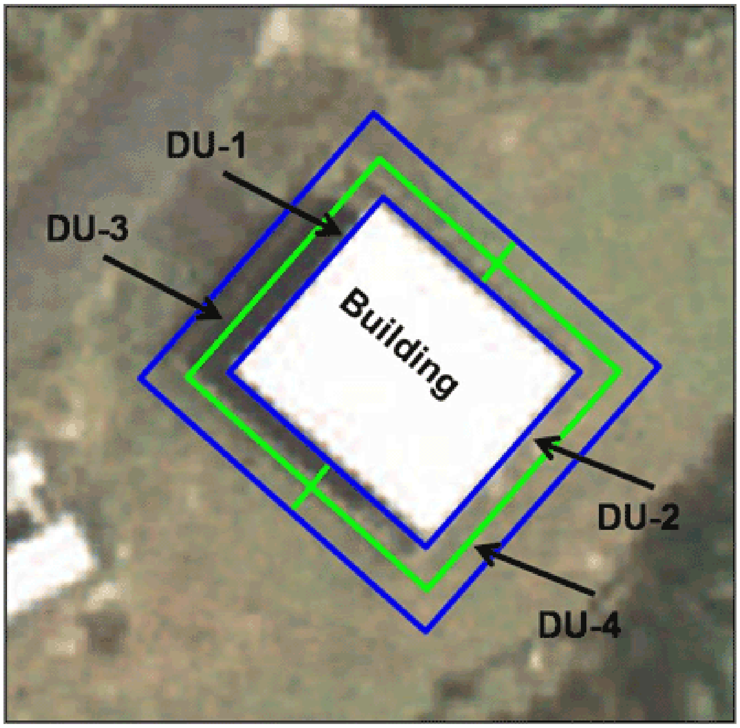

Figure 3-15. Primary (DU-1 and DU-2) and Perimeter DUs (DU-3 and DU-4) Designated Around a Building with Suspected Lead and Termiticide Contamination Perimeter DUs should also be designated and used to collect confirmation samples adjacent to and below areas of excavated soil (Figure 3-16; after ITRC, 2012).

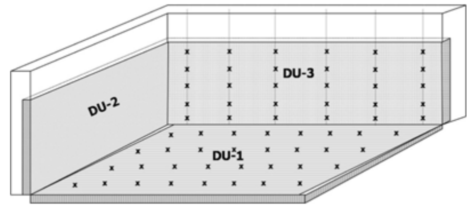

Figure 3-16. Perimeter DUs Designated Around a Planned Soil Excavation Area Samples to confirm clean boundaries ideally collected prior to soil removal to avoid need for remobilization (after ITRC, 2012)

In Figure 3-15, DU-1 and DU-2 represent hypothetical spill area DUs designated around the perimeter of a building to test for the presence of lead and termiticides in soil. These DUs are bordered by the perimeter DUs 3 and 4, which are anticipated to be outside of impacts above EALs.

Note that samples can be collected either before or after actual excavation (Figure 3-16). The confirmation of clean perimeter DUs prior to excavation is optimal, since this will negate the need for sample collection afterward and minimize concerns about the potential need for repeated over excavation. No further sampling is required if data for perimeter DUs indicate impacts below applicable action levels and soil within the DUs is completely removed.

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3.4.6 STOCKPILE DECISION UNITS

Decision unit designation and sampling strategies specific to stockpiles is provided in the HEER Office document *Guidance for the Evaluation of Imported and Exported Fill Material* (HDOH, 2017d; included as Appendix 3-A; see also Subsection 4.2.8.3 and Subsection 5.5). Background information on a stockpile should be compiled to the extent possible and used to support the sampling approach proposed in the SAP. Fill material that is imported to or exported from sites where significant environmental contamination has been identified or where cleanup projects are underway could pose multiple environmental hazards if not appropriately characterized and managed.

Special considerations for selecting DUs for sampling soil stockpiles include (see HDOH, 2017d):

Table 3-1. Default DU Volumes for Stockpiles		
Receiving Site Land Use	Default DU Volume	Comments
Unrestricted Use (includes single-family homes)	100 yd^3	Assumes 5,000 ft^2 reuse exposure area and six-inch placement thickness.
Schools and High-Density Residential Developments	400 yd^3	Assumes 0.5-acre exposure area and six-inch placement thickness.
Commercial or Industrial use only (formerly developed fill source)	400 yd^3	Assumes 0.5-acre exposure area and six-inch placement thickness.
Commercial or Industrial use only (agricultural field fill source)	400 yd^3 or 18 DUs	Stockpile divided into minimum 18 DUs for characterization if >7,200 yd^3.

Notes (Table 3-1):

1. See guidance in Appendix 3-A for additional options and recommendations (HDOH, 2011e).

- The source of the soil in the stockpile;
- How the stockpile was created (over time, if applicable);
- How best to access the pile for sampling, especially if it is large and or unstable;
- Target contaminants.

Large stockpiles could be broken or segregated into separate DUs for characterization. Default DU volumes for testing of stockpiles (or sources of fill material) are summarized in Table 3-1. Division of the stockpile should be based on soil type, source, potential for contamination, potential environmental concerns based on targeted contaminants (e.g., direct exposure vs leaching) and volume limits based on proposed reuse.

Larger DU volumes are appropriate for testing of stockpiles for reuse at high-density residential developments or schools. For example, a 400cy DU represents the approximate volume of soil necessary to cover the default, commercial/industrial exposure area of 20,000 ft^2 to a depth of six inches. A similar DU volume serves as a good starting point for testing of stockpiled soil to be used for fill material at a commercial or industrial site.

Assumed exposure areas of one-acre or more and thicknesses of one foot or more might also be appropriate for beach replenishment using dredged material not otherwise suspected to contain significantly elevated levels of contaminants. This would yield DU volumes of several thousand cubic yards. Testing of larger volumes can also be appropriate for screening of large stockpiles that are not anticipated to include contaminated soil but where some level of verification data is desired (e.g., soil from previously tested agricultural fields).

Larger DU volumes might also be acceptable for general screening purposes if other lines of evidence support a low risk of contamination based on the known source of the soil. Smaller DU volumes (e.g., 20 yd³; see HDOH, 2017d) are recommended for soil that might contain pockets of highly leaching contaminants (e.g., triazine herbicides) or contaminants that might pose potential gross contamination concerns (e.g., petroleum). Such high-resolution testing of stockpiled soil for potential reuse is likely to be cost-prohibitive, however.

Disposal of the soil with suspected pockets of highly leachable contaminants or gross contamination at a municipal landfill or long-term management at the source under an EHMP might be the most prudent option. Fill material characterization, sources of fill that should be considered suspect for contamination and other considerations are described in further detail in *Guidance for the Evaluation of Imported and Exported Fill Material, Including Contaminant Characterization of Stockpiles* (Appendix 3-A). Note that a hazardous waste determination is required for disposal of soil at a landfill (see Subsection 5.10). This could require additional sampling and analysis. Contact the landfill for specific information. Consider the inclusion of any additional testing methods and requirements in the original SAP in order address disposal needs prior to the initiation of site activities.

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3.4.7 SEDIMENT DECISION UNITS

Detailed guidance on the designation of decision units for sediment investigations is forthcoming. Sediment is defined as unconsolidated material that is currently under water (e.g., harbor bottom sediment) or otherwise associated with deposition in an aquatic environment (e.g., tidal flats, ephemeral stream beds, flood plains, etc.). Factors that affect the lateral and vertical distribution of contaminants in sediments include:

- The nature of the source area (e.g., periodic vs continuous release),
- Proximity to contaminant source,
- Sediment geochemistry,
- Size distribution of sediment particles,
- Water flow rate and volume,
- Location of depositional areas,
- Local features (natural or artificial),
- Resuspension and deposition during subsequent flood events or other disturbances,
- Vertical stratification over time,
- Seasonal fluctuations, and

- Bioturbation effects

Stratification can affect the nature of contamination at the water-sediment interface, necessitating seasonal sampling and leading to significant and abrupt vertical variability in contaminant concentrations over short distances.

These factors necessitate careful planning and thought in designation of DUs for characterization. Initial DU designation should focus on migration pathways from suspected source areas to depositional areas. Decision unit sizes and boundaries should be adjusted to address ecological impact concerns and optimization of potential remedial actions as appropriate for the investigation. Vertical designation of DUs layers might focus on the uppermost, active benthic zone, past layers of suspected high contamination, or depth intervals targeted for future dredging.

Samples will typically need to be collected from the biotic zone (e.g., the 0 to 4-inch interval) at the sediment-water interface. Deeper samples might be necessary to delineate the vertical extent of contamination to address other site-specific receptors, or characterize layers of contaminated sediment deposited in the past. If a contamination release is not recent, it is possible that later events could have resulted in deposition of a new, possibly much less contaminated sediment layer above the sediment of concern. Surface samples could result in an incomplete characterization of the DU area. Contaminated sediments currently isolated at depth could pose a threat due to storms or other erosional events or disturbance by future dredging. Conversely, clean sediment of sufficient thickness in an overall constant depositional environment may act as a cap over underlying contamination and indicate that the exposure pathway is incomplete.

Although detailed data are less available, small-scale, random variability of contaminant distribution in sediment in a lateral direction may be less dramatic than for soil in some depositional areas due to mixing during sediment transport and deposition (refer to discussion in Section 4). This could include depositional areas from runoff of agricultural, industrial or urban areas, or aquatic areas impacted by long-term discharges of industrial waste water. If this is the case, replicate field samples could document adequate sample precision with less individual increments per DU than typically utilized for soil sampling sites.

Potential distinct boundaries between clean and contaminated sediment may be anticipated with depth in areas near past contaminant source locations. This requires close consideration of the vertical resolution of a sediment investigation in terms of targeted, DU layers.

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3.4.8 INVESTIGATION OF LARGE AREAS

The guidance in this Subsection applies to characterization of soil in large open areas, where based on a thorough Phase I Environmental Site Assessment, localized spill areas are not anticipated, or have been identified and will be separately characterized. Examples include former agricultural fields, golf courses, and munitions ranges. The guidance does not directly apply to previously developed commercial, industrial, or residential areas. Characterization of these areas, as well as known or suspect spill areas within the types large areas noted above, should follow DU designation guidance presented in Subsection 3.4.

Optimal methods of employing a DU-MIS strategy for very large areas are a subject of on-going research by various organizations, and refinements of the recommendations provided below will be made in the future, as may be appropriate.

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3.4.8.1 CHARACTERIZATION FOR BASELINE INVESTIGATIONS

Baseline investigations of large areas, including agricultural fields, golf courses, and former munitions ranges might be necessary as part of a property transaction, potential redevelopment project or an evaluation of area-wide contamination. These areas can be up to hundreds or thousands of acres with dramatic changes in terrain and historical use. While still challenging logistically in the field, adhering to the same Systematic Planning process described earlier (see Subsection 3.2) will help ensure that investigation objectives are clearly defined and that meaningful data are collected.

The objective of a baseline investigation is to establish environmental impacts under current site conditions. This might include estimation of the mean concentration of residual pesticides in soil at a former golf course or in a large field that was formerly used to produce sugarcane. Other examples include assessment of soil impacts from dispersal of munitions-related contaminants across a former military target range.

The first step in this process should include completion of a thorough Phase I Environmental Site Assessment (Phase 1 ESA) covering the site history and current operations (refer to Subsection 3.1.1). The compilation and review of existing information for a former agricultural site might, for example, include the following:

- Crop history;
- Current and past pesticide use;
- Historic aerial photographs;
- Historic Sanborn Fire Insurance maps, topographical maps, or other maps;
- Interviews with former employees;
- Existing soil investigation reports (including investigations of adjacent or nearby fields using lot-size DUs);
- Review of other published, historic information (journals, etc.); and
- Field inspection (current operations, former buildings, suspect dump areas, etc.).

Decision units should be designated to characterize the site. Areas of suspected or known heavy contamination should be identified separately from anticipated less impacted areas (see Subsection 3.4.3). For example, these might include former pesticide mixing areas, storage areas, rail lines, and plantation camps for agricultural sites, and burn pits or areas immediately surrounding low-order detonations at a firing range impact zone. Designate DUs for non-suspect areas based on more localized factors including crop history, soil type, drainage patterns, etc., appropriate for the site investigation objectives and based on the information gained in the Phase I ESA. In the case of golf courses, older sections of the course where different types of pesticides were used might be characterized separately from more recent additions, and fairways might be separated from putting greens.

The total number and size of DUs will necessarily be site-specific. Use of even a single DU might be adequate to accomplish investigation objectives, although this is less likely as the size of the site increases. Past experience has suggested that 10-15 DUs are typically adequate for baseline characterization of very large areas, based on past use history, soil types, drainage patterns, etc. A better resolution of mean contaminant concentration within a single area might also be desirable, for example to verify historic information gathered on past use of the site. A Multi Increment sample should be collected to characterize each DU, with triplicate samples collected from a minimum 10% of DUs (see Section 4). See Section 9 for COPCs for pesticides. Refer to the HDOH Environmental Action Level guidance for a list of potential munitions-related COPCs (HDOH 2016).

Note that the baseline investigation approach also requires a thorough walkthrough of the entire site. This walkthrough will assist in identifying areas suspected of elevated contamination, including previously unknown dumping sites, waste pits, former plantation camp areas, pesticide mixing or storage areas, etc. that might otherwise be missed.

The results of the baseline investigation can be used to estimate the general extent and magnitude of soil contamination within the targeted area at the scale of the DUs designated. This information, in conjunction with a thorough, Phase I ESA review of the site might be adequate for the entity overseeing the investigation and their consultant to draw initial conclusions regarding redevelopment of the site for residential or other purposes. As discussed below, however, a more detailed investigation might be required for a formal site closure determination by HDOH, depending in part on the anticipated land use. For example, a baseline assessment including a strong Phase 1 report might be adequate for concurrence with future commercial/industrial use of the area, while more detailed higher-resolution data will normally be required for residential development.

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3.4.8.2 CHARACTERIZATION OF VERY LARGE AREAS FOR REDEVELOPMENT

Table 3-2. Recommendations for Investigation of Large Areas

Project Classification	Area	Recommendations
Category 1	<59 Acres	• Phase 1 ESA • One DU per acre
Category 2	>59 to <118 Acres	• Phase 1 ESA

		• 59 randomly located, one-acre DUs
Category 3	>118 to <590 Acres	• Phase 1ESA • Baseline Investigation • 59 randomly located, one-acre DUs
Category 4	>590 Acres	• Phase 1 ESA • Baseline Investigation • 90 randomly located, one-acre DUs

Recommendations provided below apply to both residential and commercial/industrial redevelopment. Characterization of very large areas for redevelopment can be challenging. Such projects can cover hundreds or thousands of acres and include hundreds or thousands of individual residential lots. The primary environmental hazard is direct exposure of future residents and workers to residual pesticides, or other contaminants such as metals in the soil. Localized contamination of highly mobile chemicals (e.g. explosives residues) can also pose potential leaching threats to groundwater that might be used to serve the redevelopment in the future.

A default Exposure Area DU size of one-acre is considered acceptable for characterization of large areas where no localized areas of potentially heavy contamination are identified as part of a thorough Phase I ESA (i.e., suspect Spill Areas; refer to Subsection 3.4.3). Variability of mean contaminant concentrations within this default DU size (i.e. at the scale of potentially smaller exposure areas) is assumed to be relatively low based on investigations of former golf courses and agricultural field areas where detailed data has been collected (e.g., refer to studies referenced in Section 9 appendices). Restriction of the default exposure area size to one-acre also helps to ensure that unanticipated, small but heavily contaminated spill areas are captured by DU data (e.g., a former pesticide mixing area). Note that if a thorough Phase 1 ESA has not been completed, the default one-acre Exposure Area DU size may be judged inadequate for evaluation (this applies to all categories of large area sites discussed below).

Table 3-2 summarizes the recommended strategy for characterization of large parcels of land where localized spill areas are not known or anticipated. Division of the site into adjacent, one-acre DUs is recommended for areas 59-acres or less in size (**Category 1, <59 acres**). Designation of DUs should reflect information garnered during the Phase I ESA to the extent practical (e.g., land-use history, terrain, soil type, etc.).

Random placement of 59, one-acre DUs is recommended for moderately large sites where the DUs will cover at least 50% of the total area (**Category 2, <118 Acres**). Testing of 59 of the total number of potential, one-acre DUs within the project area allows 95% confidence that the mean contaminant concentration in 95% of one-acre DUs at the entire site will be lower than the highest concentration reported in the one-acre DUs that were tested (USEPA, 1989b). DUs should be placed in a systematic random distribution, and with consideration to adequately represent variability associated with land-use history, pesticide use, soil type, topography and other key factors gained from the Phase I ESA investigation. Note that the 95% confidence criteria will not be met if the highest mean concentration of just one of the 59 decision units exceeds the applicable target action level. Additional sampling would typically be required to adequately identify and address areas of the site with elevated contamination. Consultation with the HEER Office to discuss potential options is recommended.

Inclusion of baseline investigation data as described above is recommended for sites where 59, one-acre DUs will cover less than 50% but at least 10% of the total project area (**Category 3, >118 to <590 Acres**). The baseline investigation should be conducted first, and will help to identify large-scale variance within the subject site and assist in subsequent DU placement and decision making. DUs should again be placed in a systematic random distribution, and with consideration to adequately represent variability associated with land-use history, pesticide use, soil type, topography and other key factors gained from the Phase I ESA investigation and the baseline investigation. For example, the baseline study might identify somewhat higher but still potentially acceptable levels of arsenic contamination in a portion of a field that was already under sugarcane production in the 1920s and 1930s (see pesticide discussion Section 9). Placement of one-acre DUs within this area or even separate characterization of this area would be warranted. Including a baseline investigation also provides some level of data for the entire project area (in addition to the 59 one-acre DUs), and helps address concerns of prospective residents who understandably might ask about soil testing data for their area.

Confidence in the representativeness of data decreases as the total area encompassed by the one-acre DUs decreases. An increase in the number of one-acre DUs to 90 in addition to a baseline assessment is recommended for projects where less than 10% of the land will be covered by the DUs (**Category 4; >590 acres**). This provides a 99% confidence that the mean contaminant concentration in 95% of one-acre DUs at the entire site will be lower than the highest concentration reported in the one-acre DUs that were tested (USEPA, 1989b).

The configuration of DUs across very large areas with respect to the planned redevelopment might also be desirable, although this could complicate usage of the data should redevelopment plans change in the future (see example in Subsection 3.5.6). HDOH feels that these recommendations are manageable in terms of the overall cost of large-scale, redevelopment projects. Alternative approaches should be discussed with HDOH on a case-by-case basis.

Decision Units should be placed in a systematic random fashion, and with consideration to adequately represent variations in site characteristics (e.g., land-use history, terrain, soil type, etc.).

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3.4.9 EVALUATION OF DECISION UNIT DATA

As discussed in Section 5, Multi Increment samples are considered to be more reliable for characterization of the mean concentration of a contaminant within a targeted DU. The evaluation of data collected from DUs is discussed in Section 13 of this guidance as well as the accompanying guidance *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH, 2016). When using a Decision Unit strategy, the entire area of a Decision

Unit is acted upon as a single entity based on the average contaminant data collected from that Decision Unit. If the decision outcome is “contaminated,” then the entire area of the DU is treated as being contaminated. If the data indicate that remediation is required, this applies to the entire Decision Unit. If the outcome is “not contaminated,” then the entire area of the DU is treated as being not contaminated. As discussed above, this makes the designation of Decision Units very important to ensure that appropriate exposure areas and/or spill areas are identified, and areas of obvious heavy contamination are segregated into separate DUs to reduce the volume of soil that is identified as “contaminated” and requires treatment.

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3.5 EXAMPLE DECISION UNITS

This Section provides example decision units for commercial/ industrial, residential, school, large area, subsurface, stockpile, and sediment sites. Examples of both exposure area and spill area decision units are included. A mixture of both types of decision units is often appropriate. The examples provided are based in part on site investigations in Hawai´i, although the placement of DUs noted in the figures has been modified to reflect lessons learned or emphasize specific points discussed in the text.

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3.5.1 COMMERCIAL & INDUSTRIAL SITES

Figure 3-17 depicts a simple spill area DU placed around a former transformer pad. The purpose of the decision unit is to investigate the presence or absence of PCB-contaminated soil in the immediate vicinity of the pad. An area extending approximately 3 feet out from the pad was selected as the DU. The pad appeared to drain to the side of the DU shown. A second DU of similar shape and size was placed on the other side of the pad. Triplicate Multi Increment samples were collected within the DU (i.e., three separate Multi Increment samples, refer to Section 4). The flags denote the location of increments collected for the first sample (approximately 30 increments per Multi Increment sample). Samples were to be tested for PCBs.

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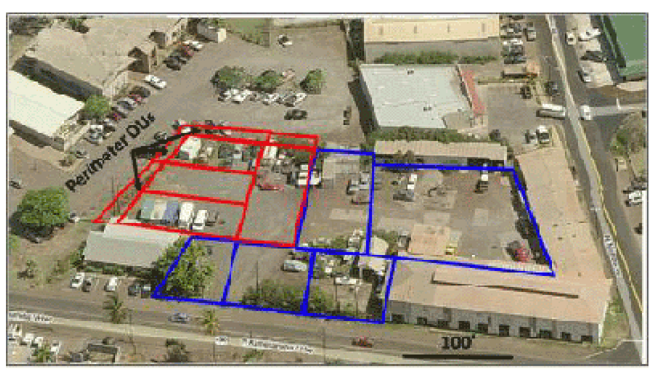

Figure 3-18. Designation of Spill Area (red) and Exposure Area (blue) DUs at a Former Electrical

Figure 3-17. Decision Unit Designated to Investigate PCB Contamination Beside Former Transformer Pad DU extended outward three feet from stained side of pad. Flags denote location of increments collected for Multi Increment sample.

Power Plant to Determine the Magnitude and Extent of PCB-Contaminated Soil. Former Transformer Storage and Repair Operations Located in Upper Left Area of the Property

Figure 3-18 depicts DUs designated for a former electric power plant. A review of historical data and previous discrete sample data suggested potential significant contamination of soil with PCBs in the area of the property where transformers were formerly stored and repaired. Relatively small DUs are designated across this area. This provides a high resolution for the distribution of PCBs across the area in order to maximize removal or remedial options. Small, perimeter DUs are designated around this area in hopes of confirming an outer boundary of clean soil. The remainder of the property where significant PCB contamination is not anticipated is divided into somewhat larger, Exposure Area DUs appropriate for the current, commercial use of the property.

Decision units designated for a former agricultural, pesticide storage and mixing area are depicted in Figure 3-19. Relatively small (100-2,000 ft^2), Spill Area DUs are designated in the former mixing tank area to evaluate potential leaching hazards posed by the triazine herbicides ametryn and atrazine (depicted in red, Figure 3-19). The DUs are designated based on obvious or suspected areas of high contamination. For example, obvious or suspected spill areas were identified on the ground under elevated mixing and storage tanks, under the floor or the storage building and in a low lying drainage area adjacent to the tanks and building (Figure 3-20). The use of small DUs helps to better assess potential leaching hazards from this area as well as optimize future remediation actions by minimizing the volume of potentially clean soil included in the DUs.

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Figure 3-19. Example Spill Area (red), Exposure Area (blue), and Perimeter Area (blue, outside ring) Decision Units for a Former Pesticide Mixing and Storage Area

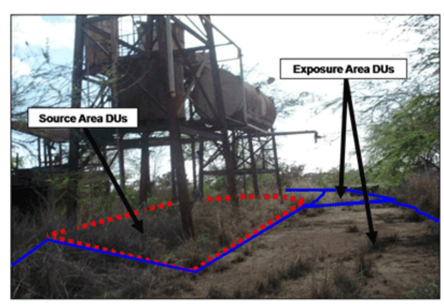

Figure 3-20. Spill Area Decision Units Designated Beneath Pesticide Mixing and Storage Tank

The remainder of the area is known from previous investigations to be contaminated with arsenic and pentachlorophenol-related dioxins with no known localized spill areas. This area was divided into eight 5,000 ft² Exposure Area DUs representing hypothetical, residential lots (see Figures 3-19 and 3-20). Two rings of lot-size, perimeter DUs were then designated around the site to establish a clean boundary and ensure that contamination associated with the pesticide mixing area has been adequately defined (refer to Figure 3-19). Decision units in the outer ring (not depicted) are tested as needed if samples from an inner ring DU failed action levels.

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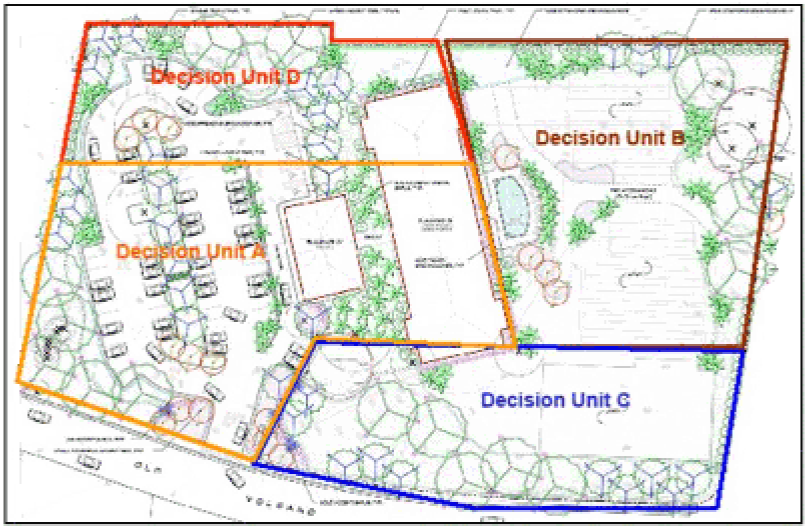

Figure 3-21. Decision Units to Investigate a Proposed, Four-Acre Hotel Site DUs A through C represent exposure areas based on the proposed hotel design. DU-D represents a suspected spill area identified during initial site investigation actions

Figure 3-22. Example Designation of DUs Around House Perimeter and Yard

Multi Increment soil samples are collected in each DU (with triplicate samples collected in two of the DUs) and are used to evaluate direct exposure hazards and leaching hazards. The full suite of COPCs is tested for in each sample. The results of the investigation and a summary of the subsequent Environmental Hazard Evaluation are carried forward as an example in Section 13.

Figure 3-21 depicts Decision Units for a proposed commercial development on a four-acre site known to be contaminated with arsenic. The property was divided into four DUs. DUs A through C represent exposure areas. DU-D represents a suspected spill area identified during initial site investigation actions. This was an attempt to isolate the most heavily-contaminated soil on the property to as small an area as possible in order to minimize future remediation and long-term management costs.

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3.5.2 SINGLE FAMILY HOMES

Soil contamination concerns for residential properties are normally limited to the presence of lead-based paint residue and organochlorine termiticides (e.g., Technical Chlordane) in soil surrounding the perimeters of wooden homes constructed prior to the mid 1970s. Termiticides could also be present beneath a building slab or in soil exposed in a crawl space, or less commonly in open areas in the yard.

Figure 3-22 depicts typical decision unit designations to investigate these potential concerns. A narrow DU (or DUs) is designated around the immediate perimeter of the home, typically within three to five feet of the foundation. The perimeter could be divided into separate DUs for testing if there is a reason to think that these areas could be different (e.g., more recent utility work or landscaping along one side of the home). The remainder of the yard or different sections of the yard can then be characterized separately as single or multiple Exposure Area DUs.

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3.5.3 HIGH-DENSITY HOUSING

The investigation of large, high-density residential areas for potential soil contamination concerns is approached in a similar manner as done for individual homes. Suspect spill areas are targeted as separate DUs for characterization (e.g., lead-based paint and termiticides around building perimeters).

The identification and management of lead-contaminated soil or soil treated with organochlorine termiticides can be a significant challenge for the redevelopment of large housing complexes. Detailed characterization around and beneath each building is often not practical (e.g., redevelopment of military or public housing complexes where dozens or hundreds of buildings will be demolished or renovated).

As an alternative, detailed characterization can be conducted for a select number of buildings (e.g., 10%) constructed during the same time period and by the same builder, with the assumption that the use of lead-based paint or termiticides around the buildings would be similar. The results could then be applied to the remainder of the buildings in order to prepare initial soil management plans. Stockpiled soil following home demolition should be tested prior to reuse or disposal if past treatment with termiticides is possible.

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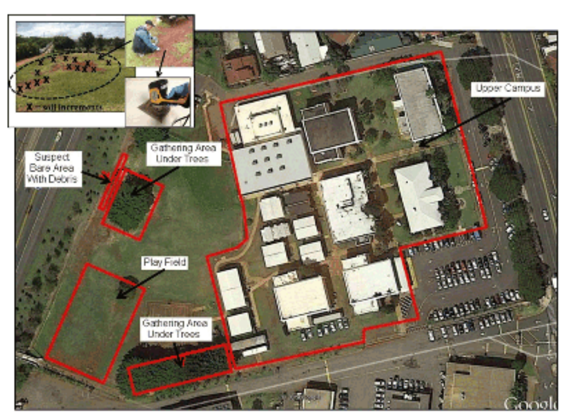

Figure 3-24. DUs Designated to Test for the Potential Presence of Lead-Contaminated Soil

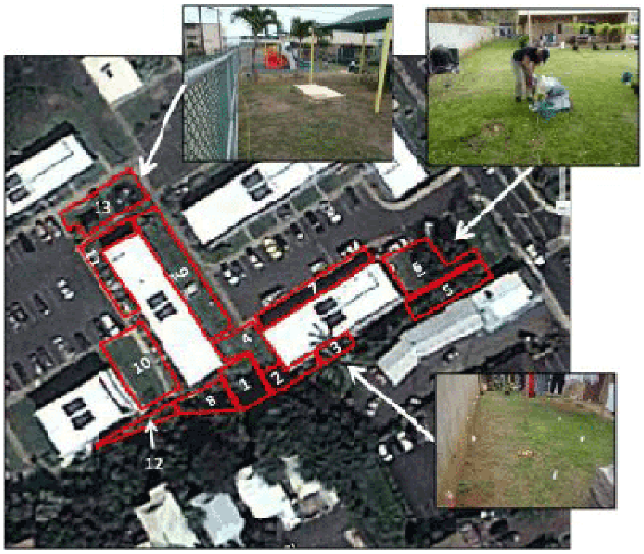

Figure 3-23. Example Designation of DUs for Investigation Pesticide-Contaminated Soil at a Public Housing Complex

at a School

As discussed in Subsection 3.4.4, the presence of termiticide-treated soil under building pads can be evaluated by the collection of soil samples from a small number of borings through the building slab. The combined sample is processed and tested in the same manner as done for a MI sample. Although the resulting data will not be reliable for estimation of mean termiticide concentrations under the slab, the presence or absence of the chemicals can be used to prepare initial soil management plans for the complex as a whole.

Open areas planned for use by residents can also be tested separately as Exposure Area DUs. This can include play areas or lawns used for recreational activities. Exposure Area DUs can also be designated for yards located in suspect areas of the property where the specific location of potential spill areas is not known.

Figure 3-23 depicts DUs designated for a public housing complex suspected of being constructed in an area where pesticide mixing and storage may have taken place in the past. Relatively small (100s to a few 1,000 ft²) DUs were designated for characterization in areas of highest concern. Designated DUs included small backyards, large open areas and playground areas. The DUs reflect exposure areas appropriate for the housing complex and also provide good resolution of mean pesticide concentrations in soil across the site.

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3.5.4 SCHOOLS

Designation of DUs for characterization of potential soil contamination at schools typically represents a combination of approaches used for commercial/industrial facilities and high-density residential complexes. Potential spill areas should be characterized separately with DUs sized to reflect the suspected extent of contamination, as well as to optimize anticipated removal or remedial actions. These could include maintenance yards, suspected termiticide-treated soil around buildings perimeters, garden areas where persistent pesticides may have been used in the past, and other areas of bare soil where children or staff may have periodic exposure.

Figure 3-24 depicts DUs designated for a school to test for the presence of lead-contaminated soil associated with dumping prior to construction of the campus. The DUs largely reflect easily recognizable exposure areas. This might include playgrounds or other gathering areas as well as gardens or open areas between buildings.

In this example a focus was made on barren areas of soil exposed in otherwise thick lawns including soil along walkways, under outdoor tables and in areas of high foot traffic. Field screening of samples from barren areas within the main campus was carried out using a portable XRF (see Figure 3-24). Soil from subareas of the upper campus was ultimately combined and tested as a single MI sample after field screening indicated similar low levels of lead within the preliminary DU as a whole.

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3.5.5 LARGE AREAS

Figure 3-25. Grouped Lots for Decision Units at a Proposed Residential Site Exposure area DUs for a former golf course based on clusters of planned houses. Red cross-hatched areas indicate suspected arsenic-contaminated soil as determined by field-based XRF.

Figure 3-26. Apparent leak under valve of large fuel tank designated as a small DU in order to document the presence of a release.

The configuration of DUs with respect to the planned redevelopment might also be desirable, although this could complicate usage of the data should redevelopment plans change in the future. An example is depicted in Figure 3-25. In this case, a former 100+-acre golf course, the property was known to contain elevated concentrations of arsenic that would require partial removal. Development plans were used to divide the property into DUs that consisted of four to five housing units each. Each DU was then tested separately for arsenic. A backhoe was used at each increment location to collect samples at depth. This allowed a three-dimensional image of soil that exceeded cleanup levels to be developed and incorporated into the site grading and soil removal plan.

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3.5.6 SMALL AREAS

Characterization of DUs as small as a few square feet and/or a very small volume of soil or sediment might be required under some circumstances. Examples include testing of upper few inches of soil under a leaking tank valve to document the presence of a release (Figure 3-26) or testing of sediment in a storm sewer vault to assess runoff from a known or suspect, contaminated area (Figure 3-27). Another example includes the desire to test a small, easily accessible portion of a suspected much larger spill area, for example the rapid collection of a soil sample from an illegal dump site (Figure 3-28). This might be done in order to document the presence of a release, identify specific contaminants of concern and establish the relative magnitude of potential contamination within the larger area as a whole.

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Figure 3-27. Stormwater drainage vault designated as a DU for testing of sediment runoff from a contaminated property. Representative sample or entire volume of sediment is collected and submitted to the laboratory for processing and analysis.

Figure 3-28. Designation of small, targeted DU within a suspected much larger area of contamination at an illegal dump site in order to document presence of contamination and identify potential contaminants of concern.

The size of DU will necessarily be site specific but should be made large enough to minimize “false negatives” and collection of a sample from a single and inadvertently clean location (e.g., three feet-by-three feet or approximately one-square meter). This is similar to the concept of “judgmental,” “biased” or “subjective” sampling under past, discrete sample collection methodologies. The data collected in judgmental sampling is only representative of the specific DU area tested, however, and while it can be used to initiate the need for a larger-scale investigation it cannot be used to quantitatively assess overall risk posed by the release.

In such cases it is important to specifically designate a DU and associated DQOs for characterization and to collect the sample in a nonbiased, "probabilistic" or "statistical" manner that ensures the resulting data will be representative of the targeted soil or sediment (refer to Section 4). This includes the need to collect a minimum, 1-2 kg of material in order to address Fundamental Error and to collect the sample from multiple, random locations within the DU in order to capture and represent random, small-scale heterogeneity (see Subsection 4.2.5). The sample must be processed for analysis at the laboratory in accordance with Multi Increment protocols again in order to address Fundamental Error (e.g., dried, sieved and subsampled; see Subsection 4.2.6). If the soil is to be tested for volatile chemicals then multiple increments from the DU can be placed into methanol in the field and submitted to the laboratory for analysis (minimum 300g recommended; see Subsection 4.2.8.1).

This approach achieves the same objectives as traditional, judgmental or "grab" discrete samples but provides much more defensible data for decision making. The potential for "false negatives," where a small mass of unrepresentatively clean soil is inadvertently collected and/or tested by the laboratory, is also minimized (refer to Subsection 4.3).

In some cases collection of the entire DU volume of soil or sediment as a single sample might be feasible. Examples include small volumes of sediment in stormwater sumps being tested to assess contaminant runoff from a property (Figure 3-27). This ideal scenario, referred to as to as "direct inference" (AAFCO, 2015), negates the need for the collection of a Multi Increment sample (and replicates) and eliminating potential field error (e.g., <2kg of material present). Importantly, the sample must be processed and subsampled for analysis at the laboratory in accordance with Multi Increment protocols in order for the data to be considered representative (refer to Subsection 4.2.6).

The concept of very small DUs also applies to targeted "DU Layer" of soil or sediment in a core where decisions are to be made on data for single boreholes (see Subsection 3.4.4). If the targeted interval of the core is less than a few feet in length then it is usually practical and even desirable to submit the entire core interval to the laboratory for processing and testing. In other cases subsampling of the core will be required to reduce the sample to a manageable mass (see Subsection 4.2.8.2 and Section 5).

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3.5.7 SUBSURFACE DECISION UNITS

Figure 3-29 depicts designation of a thin horizon that represents the top of a former dump area as a subsurface DU for characterization. The area was covered by clean fill material following closure of the dump. Subsequently, buried debris was removed as part of a redevelopment project. Soil around the perimeter of the former dump was tested for the presence of heavy metals and dioxins to determine if additional excavation was required.

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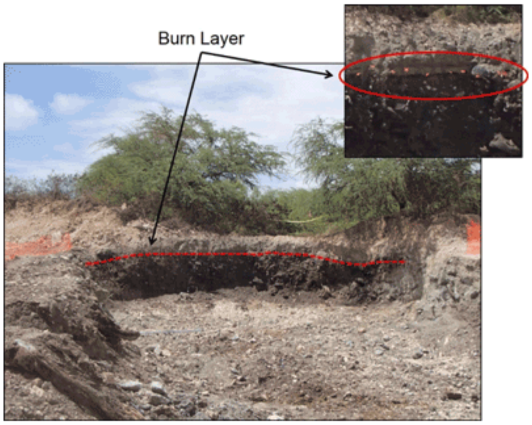

Figure 3-29. Subsurface Burn Layer Targeted for MI Sample Collection Following Excavation of Former Dump Area

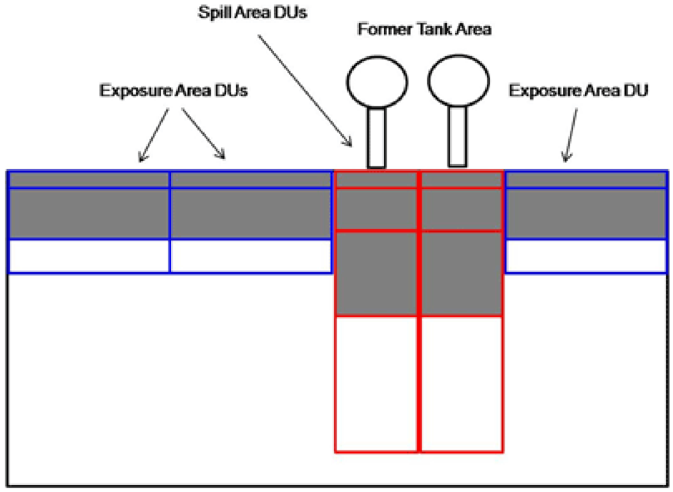

Figure 3-30. Cross Section of Subsurface DU Layers Designated at Former Pesticide Mixing Area Facility (white indicates anticipated clean soil)

The pesticide mixing area depicted in Figures 3-19 and 3-20 is used to depict a more detailed designation of DU layers for vertical characterization of the extent and magnitude of contamination. The resulting data might, for example, be used to estimate the volume and mass of soil that require excavation and disposal or the total mass of a contaminant present in soil for design of in situ treatment. Both the area and volume of DUs should be summarized in investigation work plans.

Refer again to Figure 3-19. Eight DUs of approximately 5,000 ft² each were designated for the outer area known to be contaminated by arsenic and dioxins. These contaminants primarily pose direct-exposure concerns. The DU area reflects the default size recommended for a hypothetical, single-family home residential lot. Three DUs are designated for the inner area contaminated with triazine herbicides (ametryn and atrazine), ranging in area from approximately 1,000 ft² to 2,000 ft²>. These areas primarily pose leaching and groundwater impact hazards.

Subsurface DU layers designated for the site are depicted in Figure 3-30. The thicknesses and depths of DU layers are assigned based on the anticipated depth of contamination and the desired resolution of the site investigation in terms of soil volumes for development of a remedial action plan. A higher resolution (i.e., smaller DU layer areas and volumes) increases the cost of the investigation but helps to minimize the inclusion of clean soil in treatment or removal plans. Maximum DU volumes of a few hundred cubic yards are recommended for contaminants that primarily pose direct exposure hazards (refer to Clean Fill Guidance; HDOH, 2017d). Maximum DU volumes of a few tens of yards are recommended for contaminants that pose significant leaching hazards.

In this example, arsenic and dioxin contamination in the outer part of the mixing area is assumed to be largely surficial due to the lack of distinct spill areas. Three vertical DU layers were designated (see Figure 3-30): 1) 0 to 0.5 feet, 2) 0.5 to 2.0 feet, and 3) 2.0 feet to 3.0 feet. The volumes of soil associated with the respective layers in each of the 5,000 ft² DUs are approximately 90 cubic yards, 280 cubic yards and 185 cubic yards, respectively. It is anticipated that the upper two layers will require removal. The lowermost layer is anticipated to be clean. This resolution was determined to be acceptable for development of a followup remedial action plan for this area.

Soil below a depth of two feet is divided into two DU layers in order to better assess the depth (and volume) of contamination by triazine herbicides. This is accomplished in this example by the use of smaller DUs in comparison to the arsenic- and dioxin-contaminated area. Four vertical DU layers were designated (see Figure 3-30): 1) 0 to 0.5 feet, 2) 0.5 to 2.0 feet, 3) 2.0 feet to 5.0 feet, and 4) 5.0 feet to 10.0 feet. The volumes of soil associated with the respective layers range from 20 to 50 cubic yards in shallow DU layers anticipated to be most heavily contaminated up to 185 to 370 cubic yards in deeper DU layers anticipated to be relatively clean. Contamination is anticipated to be concentrated in the upper three layers.

As discussed in Section 5, characterization of the DU layers can be accomplished by trenching and/or the installation of multiple borings. Trenching and testing of DU layers exposed in sidewalls was used to estimate depth of contamination in the outer areas. Trenching in this area was also desired to determine the presence or absence of burial pits common to these types of sites that might have been missed in previous investigations. Borings were installed in the triazine spill area, with core increments from each targeted layer collected, subsampled, and combined to produce a bulk MI sample for each layer. Triplicate samples could be collected from alternative boring locations for all or select DU layers.

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3.5.8 STOCKPILE DECISION UNITS

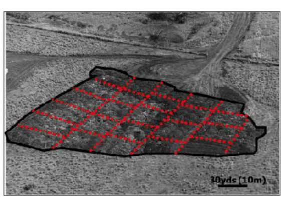

Figure 3-31. Stockpile Segregated into DU Volumes for Testing Based on Planned Reuse

Figure 3-32. DU Designation for an Investigation of Former Sugar Mill Drainage Canal DU-1 is 75 feet long and averages 10 feet wide (750 ft²). DU-2 and DU-3 are 250 feet long and again average 10 feet wide (2,500 ft²). DU sediment volume is estimated at 15 yd³ and 50 yd³, respectively.

A DU volume of 100 cubic yards (yd³) is recommended for a stockpile with an unknown history (Figure 3-31). This represents the approximate volume of soil needed to cover a hypothetical 5,000 ft² residential lot to a depth of six inches (see HDOH, 2017d; see also Subsection 3.4.2). Testing of stockpiles with an unknown history typically focuses on toxic and persistent chemicals such as arsenic, lead, organochlorine pesticides and PCBs. The presence of heavy oil is also typically tested (e.g., TPH-o). If concentrations of contaminants in each 100 yd³ volume do not exceed Tier 1 action levels then it is assumed that the soil does not pose direct exposure concerns for unrestricted reuse (e.g., residential). See Appendix 3-A, *Guideline for Evaluation of Imported and Exported Fill Material*, for additional information pertaining to sampling of stockpiles.

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3.5.9 SEDIMENT DECISION UNITS

The size of sediment DUs will vary widely depending on the nature of the release and the objectives of the investigation. Example shallow water sediment DUs are presented in Figures 3-32 through 3-36. The examples are taken from actual sites, although the details have in some cases been modified to illustrate specific points.

Figure 3-32 depicts sediment DUs designated for a drainage canal that once carried waste water from a sugar mill. Testing of surface soil at discharge points suggested that sediment in the canal might be contaminated with mercury (used as a fungicide). A relatively small DU is designated for the area of the canal immediately downstream of the discharge area (DU-1 in Figure 3-32). Two additional and somewhat larger DUs are designated for areas of the canal further downstream (DU-2 and DU-3). Two DU layers are designated, 0-6 inches and 6-12 inches. It is anticipated that contamination might be greater at depth, due to the long time interval since the cessation of operations at the facility.

The next example illustrates a single sediment DU designated at the outfall of a wastewater pipe. A single DU is designated given the anticipated similarity of impacts within the small area (Figure 3-33). The upper six inches of sediment is targeted for characterization. An 30+ increment MI sample is collected by maneuvering around the perimeter of the ponded area.

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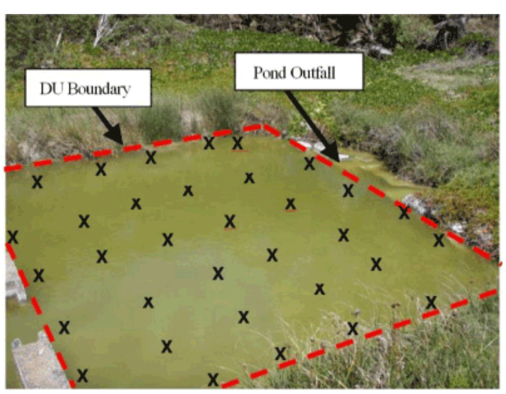

Figure 3-33. DU Designated for Characterization of Sediment at the Mouth of a Wastewater Pond Outfall "Xs" indicate increment collection locations

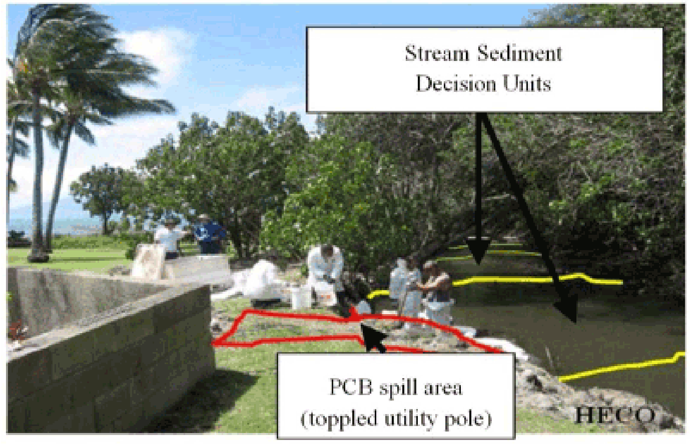

Figure 3-34. Sediment DUs Designated for a Spill of PCB-based Transformer Oil Beside a Small Stream The DUs cover approximately 500 ft² areas to a depth of six inches (approximately10cyds per DU).

Figure 3-34 depicts hypothetical DUs for a PCB spill suspected to have entered a small stream. The area outlined in red depicts the upland area impacted by the spill. Spill Area DUs as described above are used to characterize this area, including Perimeter DUs to confirm that the edges of significant impact have been identified.

Relatively small DUs, depicted in yellow, are then designated in the stream itself for characterization of sediment. The location and size of the DUs might be based on stream flow characteristics (e.g., focus on individual depositional areas, including pools and bars) and the maximum volume of sediment to be included within a DU with respect to ecological and remedial considerations. In this example, DUs approximately 500 ft² in area were considered appropriate. In this example sediment cover in the stream was very thin, three to six inches in most areas, and the entire volume of sediment within each DU was targeted for characterization (approximately 5-10 cubic yards per DU). A Multi Increment sample was collected in each DU with triplicate samples collected in 10% of the DUs.

Figure 3-35 depicts a much larger sediment investigation carried out in the upper part of a spring-fed fifty-acre estuary suspected to have been impacted by historic arsenic-contaminated wastewater and runoff from past agricultural operations in the area. The pond is tidally influenced.

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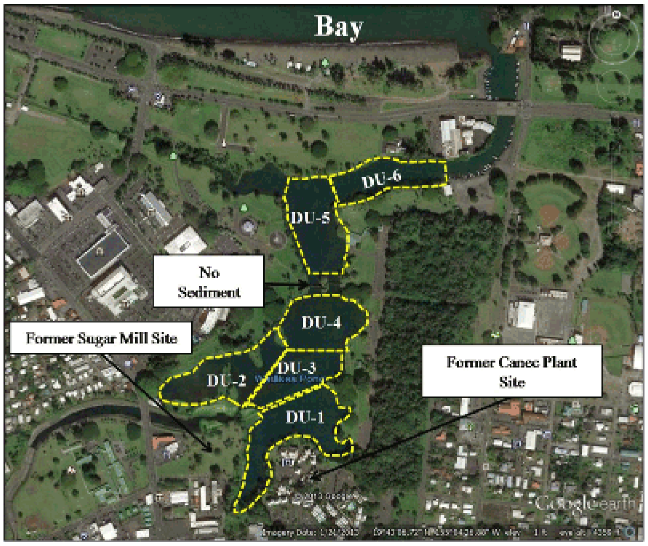

Figure 3-35. Decision Units Designated for Characterization of Arsenic-Contaminated Sediment in an Estuary

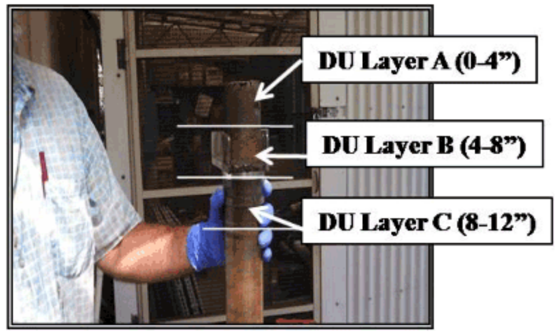

Figure 3-36. Sediment DU Layers Designated for the Estuary Example Depicted in Figure 3-35

In the example, DU-1 was placed to characterize sediment in the immediate areas of a former sugar mill and a former Canec production facility (used to make arsenic-infused, termite-resistant press-board panels from waste sugarcane fibers). The remaining DUs reflect sediment areas more distant from the former Canec plant site. The area of the pond encompassed by DUs 2 through 5 are relatively low energy and characterized by fine silts. The lower area of the pond, DU-6, is higher energy due to focused tidal action and characterized by a mix of silts to medium-grained sand. A narrow, high-energy area between DU-4 and DU-5 was not sampled due to a lack of sediment.

Vertical DU Layers may be assigned based on factors that include observations from initial test cores (e.g., distinct layering, grain size, aerobic versus anaerobic zones, etc.), characterization of benthic zones for use in ecological risk assessments, estimated depositional depth since closure of an industrial facility formerly located in the area, and/or desired resolution for potential remedial actions. In this example, the sediment in each DU was ultimately divided for testing into three DU Layers for characterization (Figure 3-36): 1) 0-4 inches, 2) 4-8 inches and 3) 8-12 inches. Methods for the collection of MI sediment samples from the DUs are reviewed in Section 4.

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3.5.10 TESTING OF DREDGE MATERIAL

Sediment targeted for dredging operations can be tested in place as described above or in stock-piles after dredging, as discussed in Subsection 3.5.7. Decision unit area and volume designation is based on targeted contaminants of concern and related environmental hazards as well as planned reuse or disposal of the dredge material. Offshore disposal of dredge material is overseen by the US Army Corps of Engineers in coordination with local environmental agencies.

Note that the use of dredge material from salty or brackish water bodies as fill material in upland areas is not recommended due to potential salinity problems. Soil salinity is evaluated in terms of Electrical Conductivity (EC) and Sodium Absorption Ratio (SAR; see HDOH, 2016). Salt intolerant plants begin to be affected by soil salinity at an EC greater than 2 mS/cm (1 milliSiemen/centimeter = 1 millimho/centimeter; see also Blaylock, 1994). Soil with an EC of greater than 32 mS/cm is toxic to even salt tolerant plants. Soil EC values of over 100 mS/cm were reported for samples of saline, dredge material collected by the HEER Office, indicating high toxicity to plants (HDOH, 2014).

Excess sodium associated with saline sediment can also cause soil to harden and form clods when dry, impeding the uptake of water during rainfall or irrigation and again reducing plant growth. A SAR value greater than 5.0 indicates sodic soils that could inhibit plant growth (see Dickson and Goyet,1994) Soil SAR values of over 200 were reported for the same dredge material noted above that was tested by the HEER Office (HDOH, 2014).

Other potential environmental concerns associated with the reuse of dredge material include runoff of saline water during rain events, as well as leaching of salt and impacts to underlying groundwater. (Note that while a high sodium content can inhibit leaching and runoff, this will also ensure that the soil remains saline and unusable for a long period of time.) Dredge material from heavily developed harbors and in the vicinity of urban runoff can also contain trace levels of other pollutants, including termiticides, petroleum, PCBs, and lead.

While the use of dredge material for beach replenishment and as fill in shoreline or near-shoreline areas may be appropriate on a case-by-case basis, the general use of dredge material from saline water bodies for fill material is not recommended without prior review and approval by HDOH. The HDOH Office of Solid and Hazardous Waste should be contacted for additional guidance and regulatory information on the reuse of dredge material.

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3.6 SAMPLING AND ANALYSIS PLANS

The Sampling and Analysis Plan (SAP), developed during Step 6 of systematic planning, specifies the final design and configuration of the environmental measurement effort required to resolve issues and questions stated in the systematic planning steps (Steps 1-5). The SAP is a comprehensive document that would enable an experienced field sampling team unfamiliar with the site to come in and examine the site and collect the required samples and field information. The SAP designates the types and quantities of samples or monitoring information to be collected; where, when and under what conditions they should be collected; the variables to be measured; and the Quality Assurance/Quality Control (QA/QC) procedures to ensure that sampling design and measurement errors meet the tolerable decision error specified.

The QA/QC procedures are described within the Quality Assurance Project Plan (QAPP), which is included within the SAP. The site-specific Health and Safety Plan is also included as part of the overall SAP (alternately, the Health and Safety Plan can be presented with the SAP in a site Work Plan). The SAP must be flexible and dynamic to deal with unexpected discoveries or circumstances that may be encountered during the site investigation. To ensure appropriate characterization of the site and to minimize the need to perform additional sampling, it is recommended that SAPs be reviewed and approved by the HEER Office. In addition, it is important to consult with the laboratory while developing the SAP to ensure objectives are in alignment with chosen laboratory practices, and to provide contingencies for matrix problems that may occur. Important among such issues to discuss with the laboratory are expectations for storing remaining portions of MI samples that have been analyzed, until site sampling decisions are completed. Based on initial data analysis or new information, additional analyses may be conducted from stored bulk MI samples rather than having to mobilize and collect additional samples in the field.

The suggested outline for the SAP is as follows:

1. Introduction
2. Site Background
   1. Site description
   2. Site characteristics
3. Investigation History
4. Site Investigation Objectives
5. Scope of Work
6. Description of Sampling Activities
7. Analytical Methods
8. Quality Assurance Project Plan
9. Documentation and Reporting
10. Schedule
11. Health and Safety Plan
12. References

More detailed information regarding the outline, format, and required content of the SAP is presented in Section 18.

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3.6.1 SAMPLE COLLECTION STRATEGY

A sampling strategy should reflect the approach that will best meet investigation objectives within acceptable uncertainty limits, with consideration taken for efficient use of time, money, and human resources. Section 4 discuses sample collection strategies for soil and sediment.

Sample collection for soils generally falls under two main categories: Multi Increment samples and discrete samples (see Section 4):

- The HEER Office strongly encourages the use of Multi Increment/Decision Unit strategies to investigate contaminated soil. Multi Increment samples are collected using a probabilistic sampling theory and involve the collection of a large number of increments (30-100) from within the target DU. Each increment is made up of approximately 5 to 50 grams of soil. The increments are combined to form a single, Multi Increment sample for the DU. A detailed discussion of Multi Increment sampling approaches is provided in Section 4.
- Discrete samples (i.e., samples typically consisting of only one increment) are collected using either random or biased sample point locations based on professional judgment. In some cases, groups of discrete samples are combined for analyses. A small number of discrete samples are typically not representative of average contaminant levels in a specific DU as are Multi Increment samples, and therefore not recommended in most cases. Discrete sample data can, however, prove useful at the early stages of a site investigation,

especially when available from previous studies. This includes screening sites for the presence of large spill areas not obvious in the field, and providing data to help select DU boundaries for collection of more detailed Multi Increment samples (see Subsection 4.3).

See Section 6 for sample collection strategies for groundwater, and Section 13 for information and references regarding ecological risk evaluations.

Information regarding sampling design is also available in USEPA's *Guidance on Choosing a Sampling Design for Environmental Data Collection* (USEPA, 2002f), although the guidance focuses on the collection of discrete samples. Software is available to assist in designing a sampling strategy, although again, they are primarily applicable to discrete sampling approaches. One example is Visual Sample Plan [VSP] software available from Pacific Northwest National Laboratory (PNNL, 2005).

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3.6.2 SAMPLING COLLECTION METHODS

After the sampling design is determined, sampling methods are selected to facilitate the sampling design. Sampling methods are specific to the sampling design and the needs of the site and are selected to meet requirements of the site investigation objectives and associated DQO.

Sampling design approaches are discussed in Section 4.Sampling soil DUs at depth typically involves additional time and resources compared to DUs for surface soil (refer to Subsection 3.4.4 and Section 4). Several sampling approaches might be useful for a given site. Sampling method procedural guidance for soil and sediment, groundwater and surface water, and soil vapor and indoor air is presented in Sections 5, 6, and 7, respectively. The application of Decision Unit approaches is recommended for characterization of sediment and surface water as well as soil.

3.6.3 HEALTH AND SAFETY PLANS

Hawai'i hazardous substance release sites fall under the definition of "uncontrolled hazardous waste sites" pursuant to Occupational Safety and Health Administration (OSHA) Hazardous Waste Operations and Emergency Response (HAZWOPER) Title 29 Code of Federal Regulations (CFR) Section 1910.120(a)(1). A health and safety plan (HASP) is required under Title 29 of the Code of Federal Regulations, Section 1910.120 (Hazardous Waste Operations and Emergency Response), which includes a requirement for a hazard communication program meeting the requirements of 29 CFR 1910.1200. Like rules were adopted under Hawai'i Administrative Rules (HAR) Title 12, Chapters 60 and 203.1, Division of Occupational Safety and Health Standards. The Health and Safety plan is typically a part of the SAP (or alternately, part of the site Work Plan). The HEER Office recommends that an employer develop a written Health and Safety Plan, which includes the following elements:

• An organizational structure • A comprehensive work plan	• Standard operating procedures for health and safety • Any necessary interface between general program and site-specific activities

• A site-specific health and safety plan • A health and safety training program • A medical surveillance program	

The OSHA HAZWOPER Standard, Title 29 CFR 1910.120, requires that personnel working in and around hazardous waste have a site-specific HASP and competent safety officers to enforce health and safety rules. OSHA has determined that employees must be trained if they work in proximity to hazardous chemicals with a potential for release or substantial threats of release, without regard to the location of the hazard.

An OSHA-certified 40-hour class focusing on HAZWOPER training is required for those who are performing regular work on hazardous waste sites; an annual 8-hour refresher course is required to maintain the certification achieved through this training. An OSHA-certified 24-hour course is required for those who have occasional exposure to hazardous waste. In addition, an 8-hour course is required for supervisors and management personnel who oversee hazardous waste projects. The amount of training required is contingent upon an employee's responsibilities and involvement with hazardous materials; these must be clearly established by the employer and communicated to the employee(s). The HEER Office does not approve Health and Safety Plans, but does require that one be in place for field activities at hazardous chemical release (or suspect release) sites. Contact the Hawaiʻi Division of Occupational Safety and Health (HIOSH) for detailed information on HASPs and organizations offering HAZWOPER training.

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3.7 QUALITY ASSURANCE PROJECT PLANS

Data acceptance criteria, developed during Step 5 of systematic planning, are presented in the Quality Assurance Project Plan (QAPP) which is the formal project document that specifies the operational procedures and QA/QC requirements for obtaining environmental data of sufficient quantity and quality to satisfy site investigation objectives. The QAPP is required for all data collection activities that generate data for use in decision-making. It contains information on project management, measurement and data acquisition, assessment and oversight, and data validation and usability. The QAPP integrates the DQO, the data collection design, and QA/QC procedures into a coherent plan to be used for collecting data that are of known quality and adequate for their intended use. The QAPP is typically presented as part of the SAP (Step 6 of systematic planning) and should include the following elements:

1. Quality assurance (QA) objectives for measurement
2. Sample chain of custody
3. Calibration procedures
4. Analytical methods
5. Data reduction, validation, and reporting
6. Internal quality control (field and laboratory checks)

7. Performance and system audits
8. Preventative maintenance
9. Data measurement assessment procedures (precision, accuracy, and completeness)
10. Corrective actions

Participation of the laboratory that will be utilized is important to ensure capabilities are agreed upon and not assumed. Other considerations such as potential changes to cleanup processes, lab filtration, etc. should be discussed ahead of time when potentially contaminated samples are collected.

More detailed information regarding the outline, format, and required content of the SAP, which includes the QAPP, is presented in Section 18.

Additional information regarding the development of a QAPP is available in the Uniform Federal Policy for Quality Assurance Project Plans (USEPA/DoD/DOE, 2005), Guidance for Conducting Remedial Investigation and Feasibility Studies under CERCLA (USEPA 1988), and Guidance for Quality Assurance Project Plans (USEPA, 2002g). In addition, Data Quality Assurance and Quality Control procedures are discussed in detail in Section 10.

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3.8 DATA QUALITY ASSESSMENT

After the environmental data are collected, the data are validated in accordance with the QAPP. This data validation and assessment process establishes whether the type, quantity, and quality of sampling data are adequate to support the decision making process (Data Quality Assessment – DQA). Data Quality Assessment is performed during Step 8 of systematic planning. Given the quality of the data collected, the DQA process will verify if the estimated contaminant concentrations at the site meet the level of confidence specified in the SAP. Additional information regarding data validation and data quality assessment is available from USEPA in Guidance for Data Quality Assessment: Practical Methods for Data Analysis (USEPA, 2000d) and Data Quality Assessment: A Reviewer's Guide (USEPA, 2006).

3.8.1 DATA VALIDATION

Data validation is the process used to determine if the environmental data are accurate; specifically, it assures that methods specified in the SAP and QAPP were correctly specified on the chain of custody document(s) and carried out by the laboratory such that the data are useful for its intended purpose(s). The data validation process begins at the analytical laboratory. The laboratory analyst verifies instrumental data, calculations, transfers, and documentation, and corrects errors, if detected. The laboratory provides QA/QC information to assure data validity. Labs selected for conducting analyses should have well-documented QA/QC procedures. Participation in established lab certification programs such as the NELAC certified laboratory program can help to establish that a laboratory has well-documented QA/QC procedures that are periodically audited by the certifying body. Technical department managers, quality control specialists, or project managers should review the laboratory data reports and supporting documentation.

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3.8.2 DATA QUALITY ASSESSMENT PROCESS

Data Quality Assessment (DQA) is a five step process with the goal of determining whether the type, quantity, and quality of sampling data are adequate to support the decision making process.

Step 1: Review the DQO and Sampling Design

Review the DQO and sampling design to ensure the issues at the site have been adequately addressed. If data are not sufficient to move forward with selection of a remedy or other next step, additional sampling may be required. For example, if sampling did not delineate the vertical or horizontal extent of contamination, or if groundwater was not encountered due to drilling refusal at a site where groundwater was believed to be impacted; then additional sampling would typically be required.

Step 2: Conduct a Preliminary Data Review

Conduct a preliminary data review. Start with a review of the data validation assessment. Look for data patterns, relationships, or potential anomalies.

Step 3: Select the Statistical Method

Select statistical methods to assess the data. During the DQO development process, limits on decision error tolerance are specified. Uncertainty limits are typically proposed by establishing performance goals of the analytical data for precision, accuracy, repetitiveness, completeness, and comparability parameters. In addition, uncertainty limits and performance data are developed in more detail in the QAPP (See Subsection 3.7). Examine uncertainty limits through statistical evaluation, which is an important tool used in the data assessment to determine:

- Whether the data meet the assumptions under which the DQO and the data collection design were developed
- Whether the total error in the data is small enough to indicate that the data are of sufficient quality to support decisions within the tolerable error rates expressed in the DQO

During field sampling, a triplicate sample is typically collected in one DU for each batch of up to 10 similar DUs to allow for statistical calculation of several important quantities including the standard deviation of the mean, the relative standard deviation (RSD) of the mean and/or the 95% UCL of the mean. These quantities are the statistical measures that are typically selected for evaluating the overall precision of the contaminant sampling. Use of field sampling replicates and laboratory subsampling/analysis replicates to evaluate MI sample precision allows consideration of total sampling error (a combination of field sampling/field processing error and laboratory subsampling and analysis error), as well as evaluation of the magnitude of field sampling error compared to the laboratory subsampling and analysis error. The latter is evaluated by subtracting the laboratory subsampling/analysis error (the laboratory replicate data) from the total error (the field replicate data) to determine the magnitude of the field sampling error.

Step 4: Verify the Assumptions of the Statistical Method

Evaluate whether the underlying assumptions of the statistical methods hold, or whether departures are acceptable, given the actual data.

Step 5: Draw Conclusions from the Data

Draw conclusions about the data collected. Discuss the validity of the data that do not meet the performance criteria established in the DQO.

Note: The HEER Office requires that an Environmental Hazard Evaluation be prepared and submitted with a site investigation report. Representative COPC concentrations developed as part of this evaluation may involve further statistical evaluation, including, for example, the assessment of non-detect data. A detailed discussion of Environmental Hazard Evaluations is presented in Section 13.

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3.9 SITE INVESTIGATION REPORTS

Accurate and thorough documentation of the sample plan design, sample collection and handling procedures, laboratory analyses, data assessment, and a summary of the data collected are crucial to the site investigation. The laboratory selected should adhere to a comprehensive Quality Assurance Plan and SOPs for sample analyses. The HEER Office strongly encourages active communication, including draft report reviews and subsequent meetings or conference calls, to prevent costly remobilizations to collect additional data. The following reports (and major elements) are typically prepared and submitted to the HEER Office for review.

- Sampling and Analysis Plan
  - Sampling design
  - Preliminary Conceptual Site Model
  - Preliminary site investigation objectives and DQO
  - QAPP
  - Safety and Health Plan
- Site Investigation Report
  - Site history
  - Site investigation objectives (including DQO)
  - Selection of Decision Units, including replicates
  - Figures displaying all DU locations on site
  - Identification of information needs
  - Sample collection and analysis methods

- Summary of analytical results
- Data assessment
- Summary of extent and magnitude of contamination
- Preliminary Environmental Hazard Evaluation
- Conclusions and recommendations

Additional guidance on report formats and content is presented in detail in Section 18. The HEER Office requires that the lateral and, as needed, vertical extent of soil and groundwater (and in some cases soil gas) contamination be clearly depicted on to-scale maps and cross sections of the site. Shading or other graphics should be used to depict DUs suspected to be contaminated above levels of potential concern. This information is then used in the Environmental Hazard Evaluation to identify specific environmental hazards posed by the identified contamination as well as the specific areas of the site where these hazards are present (see Section 13). The results of the preliminary Environmental Hazard Evaluation may require that additional data be collected at the site (e.g., soil gas data to evaluate potential vapor intrusion concerns) or that additional tests be carried out on existing samples. After all environmental hazards are adequately identified, delineated and evaluated, the final Site Investigation and Environmental Hazard Evaluation reports are used to support and assist in the development of appropriate response actions.

Not all projects will require that formal sampling plans and related reports be submitted prior to initiating site investigation activities; this will vary from site to site and should be discussed with the overseeing project manager in the HEER Office.

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3.10 ENVIRONMENTAL HAZARD EVALUATION

An Environmental Hazard Evaluation is the link between site investigation activities and response actions, if needed (refer to Figure 3-1). A detailed discussion of Environmental Hazard Evaluation, including EALs, is provided in the HDOH document *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH, 2016). An overview of the document is provided in Section 13.

As noted previously, the collection of site data and the identification of potential environmental hazards are iterative processes. Environmental Hazard Evaluations as well as CSMs should stress fate and transport of COCs. As initial site data indicate potential environmental hazards, the need for additional data to fully define and evaluate the hazards and develop appropriate response actions must be evaluated. The identification of potential hazards early on during site investigation activities, even at a cursory level, can help guide the progression of fieldwork and reduce the need for continual remobilization and collection of additional data.

Screening field data for the presence of potential environmental hazards as soon it arrives from the laboratory is a critical step in the site investigation process and should not be delayed pending the completion of a formal site investigation report. In the absence of obvious conditions in the field (e.g., explosive levels of soil vapors), the most expeditious approach to identifying potential environmental hazards associated with contaminated soil or groundwater is a direct comparison of site data to the HDOH Tier 1 EALs (see Section 13).

The presence or absence of potential environmental hazards can be quickly identified by direct comparison of site data to HDOH Tier 1 EALs. If the reported concentration of a COPC exceeds the Tier 1 EAL in the subject media (e.g., soil, soil gas, or groundwater) then the specific environmental hazard(s) potentially posed by the chemical should be identified (see Subsection 3.3.2). Exceeding the Tier 1 EAL does not necessarily indicate that environmental hazards are present, only that further evaluation is warranted. Perhaps most importantly, use of the Tier 1 EALs allows site owners/operators, consultants, and regulators to quickly screen out contaminants that do not pose potential concerns and negate the presence of environmental hazards at sites with minimal contamination. This is most easily done using the HDOH EAL Surfer available for download from the HDOH Environmental Hazard Evaluation web page).

As potential environmental hazards are identified, the CSM for the site should be updated and the need for additional sample data evaluated. For example, the identification of elevated levels of lead in soil samples from one area of the site may indicate a need for additional soil samples from that area to better define the extent of contamination. The identification of potential leaching hazards associated with a COPC suggests that batch testing and/or groundwater data may be needed. The identification of potential vapor intrusion concerns suggests that soil gas data are needed.

Applying this type of dynamic and iterative approach to the site investigation process will expedite completion of the investigation and approval by the HEER Office. Screening preliminary data up front allows for a more complete site investigation to be prepared and submitted. This reduces the need for remobilizing months (or even years) after the initial sampling event and the need for multiple and time consuming reviews of site investigation reports by the HEER Office. Informal meetings with a HEER Office project manager or technical support staff person to discuss preliminary data and propose additional actions as the site investigation is being carried out are highly encouraged.