State of Hawaii, Department of Health
HEER Office

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SECTION 13

ENVIRONMENTAL HAZARD EVALUATION
INTERIM FINAL – SEPTEMBER 19, 2017

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13.0 ENVIRONMENTAL HAZARD EVALUATION

This section provides an overview of the HDOH HEER Office approach to **Environmental Hazard Evaluation**, as described in the separate guidance document *Screening for Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH, 2016). Environmental Hazard

Evaluation (EHE) is the link between site investigation activities and response actions carried out to address hazards posed by the presence of contaminated soil and groundwater, as shown in Figure 13-1.

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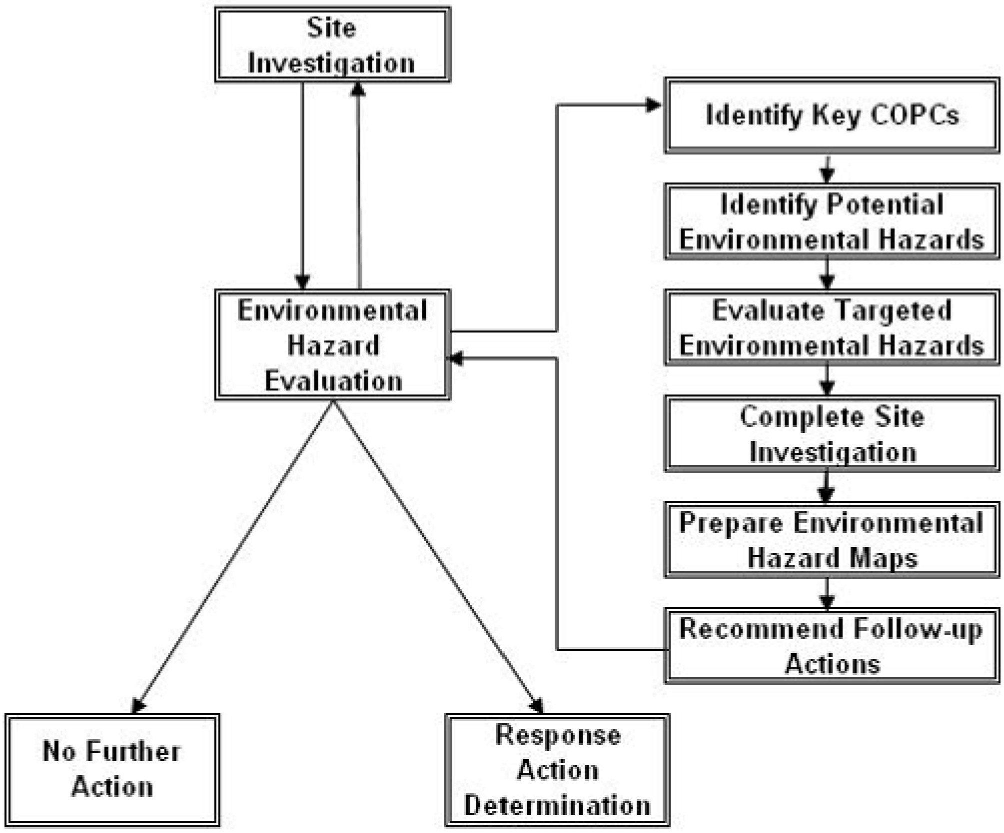

Figure 13-1. Expanded Overview of the Environmental Hazard Evaluation Process. Note: COPC = Chemicals of Potential Concern.

In this step of the site assessment process, the presence or absence of potential environmental hazards associated with contaminated soil and groundwater is determined and summarized in an EHE (i.e., a review of potential environmental hazards), which must be carried out for all sites. As discussed below, the level of detail needed in an EHE will vary, depending on the extent and nature of contamination. This is most easily done at a screening level by comparison of site data to HDOH Tier 1 Environmental Action Levels (Tier 1 EALs). When the presence of a potential hazard(s) is confirmed, the specific hazard posed by the contamination is identified and the scope of follow-up actions necessary to address the hazard(s) is determined.

Once the site has been adequately characterized and potential environmental hazards identified, an appropriate response action is determined. If contamination is not identified above HDOH Tier 1 EALs then no further action is necessary. For sites where the extent of contamination that exceeds Tier 1 EALs is minimal or time is of the essence, the most cost-effective response may simply be disposal or treatment of the contaminated media. The Tier 1 EALs are *not* strict, regulatory cleanup standards, however. The practicability of full remediation in terms of access, anticipated land use, use of engineered and institutional controls, public acceptance, cost and other factors should be considered before final remedial actions are developed (refer also to Sections 14, Section 16, and Section 19).

A more detailed evaluation of specific environmental hazards is usually warranted at sites where contamination is identified above HDOH Tier 1 EALs. This could include the need for additional site data (e.g., soil gas data, bioaccessible arsenic data, etc.), the development of more site-specific cleanup levels, identification of the most pressing hazards (e.g., discharges of free product into storm sewers, vapor intrusion into overlying buildings) and other site-specific considerations. Contamination left in place following remediation of the site to the extent practicable and the specific environmental hazards posed by the contamination are documented in the final Site Investigation and Environmental Hazard Evaluation reports. This information is then used to prepare an **Environmental Hazard Management Plan** that describes actions for long-term management of the contamination (see Sections 18 and Section 19).

Environmental Hazard Evaluation is therefore an integral part of both site investigations and response actions. Site investigations and response actions carried out in the absence of a basic understanding of environmental hazards posed by contaminated soil or groundwater run the risk of being incomplete, and require unanticipated, additional field work. This can result in unnecessary delays and costs in addressing contamination issues and bringing the property back into productive use. The guidance presented in this document is intended to help avoid these types of problems and make the site assessment process as effective and efficient as possible.

A summary of the Environmental Hazard Evaluation process is presented within this section. A detailed description of Environmental Hazard Evaluations and associated Tier 1 Environmental Action Levels is presented in a separate guidance document entitled *Screening for Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH, 2016). Readers unfamiliar with the concept of environmental hazard evaluation may be familiar with the concepts of human health risk assessment and ecological risk assessment. As discussed below, human health and ecological risk assessment are two important components of the broader concept of environmental hazard evaluation. Traditional risk assessments may not adequately address all potential environmental concerns at a site, and cannot be used as a replacement for Environmental Hazard Evaluation. Note that in earlier HEER Office guidance this process was referred to as Environmental Hazard *Assessment*. The term *assessment* has been changed to *evaluation* in this guidance to help avoid confusion with traditional health and ecological risk assessment.

Additional information on the evaluation of environmental hazards associated with petroleum contamination (as well as other contaminants) is discussed in Section 9 and the primary EHE guidance (HDOH, 2016; see also HDOH, 2007).

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13.1 TARGET ENVIRONMENTAL HAZARDS

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Table 13-1 Target Environmental Hazards by Media

Environmental Hazard	Description
Contaminated Groundwater	
Human Health Risk	
– Drinking Water	Toxicity concerns related to contamination of groundwater that is a current or potential source of drinking water
– Vapor Intrusion	Emission of volatile contaminants from groundwater and intrusion into overlying buildings
Aquatic Habitats	Discharges of contaminated groundwater and toxicity to aquatic organisms. Includes contamination of fish and shellfish used for human consumption.
Gross Contamination	Includes taste and odor concerns for contaminated drinking water supplies, free product, sheens and odors on surface water, general resource degradation, etc.
Contaminated Soil	
Human Health Risk	
– Direct Exposure	Exposure to contaminants in soil via incidental ingestion, dermal absorption and inhalation of vapors or dust in outdoor air.
– Vapor Intrusion	Emission of volatile contaminants from soil and intrusion into overlying buildings
Leaching	Leaching of contamination from soil by infiltrating surface water (rainfall, irrigation, etc.) and subsequent contamination of groundwater resources
Terrestrial Habitats	Toxicity to terrestrial flora and fauna
Gross contamination	Includes potentially mobile free product, odors, aesthetics, explosive hazards, general resource degradation, etc
Contaminated Soil Gas	
Explosions	An explosion hazard can exist if accumulation of unstable gases such as methane or Total Volatile Hydrocarbons (TVH) occurs in confined spaces.
Vapor Emissions	Emission of volatile contaminants from soil or groundwater into overlying buildings and/or outdoor air.

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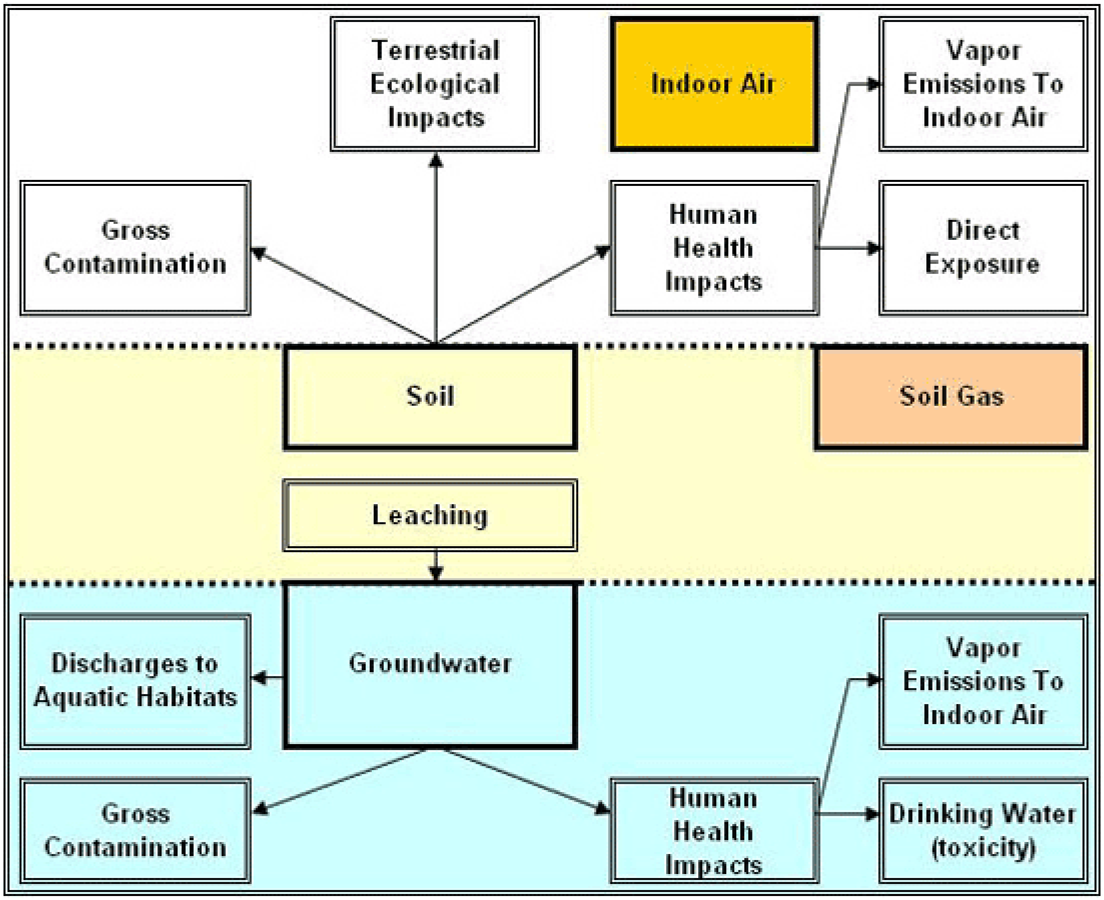

Figure 13-2. Summary of Environmental Hazards Considered in Action Levels. The four target media tested to evaluate these potential hazards are groundwater, soil, soil gas and indoor air.

A summary of common environmental hazards that should be initially screened for at contaminated sites is given in Table 13-1 (see also Figure 13-2)):

The potential for one of more of these environmental hazards to be present at a site should be evaluated in an EHE, which should include screening sample data if available. As discussed in Section 3, preparation of a conceptual site model that summarizes current site conditions is an important part of the EHE process.

Note that some of the environmental hazards listed above are not necessarily "risk-based," at least in the traditional toxicological use of this term with respect to dose and response. For example, soil that is grossly contaminated with petroleum may not pose a toxicological risk to future residents, but it could pose significant odor and nuisance concerns and in some cases even result in explosive levels of vapors in soil gas. Although it may seem counterintuitive, it is quite possible for soil that is flammable to be considered "nontoxic" in a standard human health risk assessment. Even so, the fact that the soil is flammable is important to call out in the Environmental Hazard Evaluation. Gross contamination can also complicate future construction or subsurface utility activities that require disturbance of heavily contaminated soil or groundwater.

Leaching of contaminants from soil is also important to consider, even though this is rarely included in traditional risk assessments. Discharges of contaminated groundwater or free product into nearby surface water bodies, either naturally or via leakage into storm sewers or through site dewatering activities, can pose significant environmental hazards to aquatic habitats. When large plumes of impacted groundwater threaten fisheries, the discharge of contaminated groundwater to surface water and subsequent uptake of contaminants into seafood may also be of concern. This includes the biomagnification of contaminants up the food chain and risks to human or ecological health if contaminated fish or shellfish is ingested.

The environmental hazard that drives the potential need for remedial action at a contaminated site is closely tied to the toxicity and mobility of the targeted contaminants. Concerns posed by soil contaminated with chemicals that are highly toxic to humans and relatively immobile are generally driven by direct exposure hazards (e.g., arsenic, lead, polychlorinated biphenyls [PCBs]). Vapor intrusion typically drives environmental hazard for soil contaminated with volatile carcinogens, although direct exposure and leaching hazards are not far behind (e.g., benzene, tetrachloroethylene [PCE], TPH gasoline, methane). Leaching hazards will often drive cleanup of soil contaminated with noncarcinogenic chemicals that are highly mobile (e.g., TPH gasoline or diesel, toluene, xylenes, chlorinated herbicides). Soil contaminated with pesticides or metals that are relatively non-toxic to humans and immobile could still pose significant toxicity hazards to terrestrial flora and fauna (e.g., barium, copper, nickel).

Drinking water toxicity hazards are almost always identified for contaminated aquifers. Potential vapor intrusion hazards will also usually be identified for groundwater contaminated with carcinogenic, volatile chemicals. Chemicals that have a low taste and odor threshold may not pose toxicity concerns but can still pose gross contamination hazards for drinking water resources (e.g., TPH, ethylbenzene, toluene, xylenes). A number of pesticides pose aquatic toxicity hazards at concentrations well below drinking water standards. This can drive remedial actions if discharge of contaminated groundwater into a sensitive aquatic habitat is possible. Free product could pose both toxicity and gross contamination hazards if allowed to migrate offsite and discharge into a surface water body. Free product also poses potential vapor intrusion hazards for nearby buildings as well as potential explosive, subsurface vapor hazards.

Other potential environmental hazards may require attention at some sites, including exposure of construction workers to contaminated groundwater and the potential uptake of contaminants in garden produce. The need to include additional environmental hazards in the site assessment must be determined on a site-by-site basis.

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13.2 DEVELOPMENT OF VAPOR INTRUSION SCREENING TOOLS

The collection of soil vapor samples as part of a site characterization and vapor intrusion investigation is discussed in Section 7. The technical background and development of soil vapor and indoor air action levels for assessment of potential vapor intrusion hazards is presented in the HDOH Environmental Hazard Evaluation (EHE) guidance (HDOH, 2016.). The guidance also presents soil and groundwater action levels for screening of potential vapor intrusion hazards. The collection of soil vapor data is recommended for all sites where potentially significant releases of volatile chemicals might have occurred.

A key factor in development of the action levels for potential vapor intrusion risks is the assumed attenuation of subsurface vapors as they intrude a building and mix with indoor air. Assumptions incorporated into the vapor intrusion models are discussed in Sections 2 and 3 of Appendix 1 of the EHE guidance and based on research published by Brewer et al. (Brewer et al., 2014b.). The research represents an important update to indoor air:subslab soil vapor attenuation factors initially proposed by USEPA researchers in the early 2000s and published for public review in 2012 (USEPA 2012b.).

The “empirical database” used to derive the 2012 USEPA attenuation factors was subsequently determined to be unreliable (Brewer et al. 2014b.). The database relied on a single, small-volume (e.g., one-liter), randomly located, subslab vapor sample to represent intruding vapors (attenuation = indoor air sample concentration/subslab vapor sample concentration). Attenuation factors derived from the database were an order of magnitude or more higher (i.e., less attenuation) than attenuation estimated from more rigorous databases of building leakage used by engineers to design heating and cooling and energy systems, and were called into question. Use of the excessively high (“conservative”) attenuation factors caused large numbers of sites with relatively minimal VOC contamination to be unnecessarily flagged for potential vapor intrusion risks.

Reliability of the approach used by USEPA required a high degree of uniformity of VOC concentrations in vapors beneath building slabs. Collection of a vapor sample from another location under the building slab would otherwise generate a different attenuation factor, implying that any single attenuation factor estimated was random and unlikely to be representative of actual vapor intrusion conditions. As discussed by Brewer et al. (Brewer et al., 2014b.), subslab vapor plumes are in fact likely to highly heterogenous. This, in addition to uncertainty regarding actual vapor entry points into a building, negates the validity of the USEPA database for derivation of indoor air:subslab attenuation factors. As an alternative, Brewer et al. (Brewer et al., 2014b), refer back to the original approach proposed by USEPA (USEPA, 2004f.) based on better supported building leakage rates in various climate regions within the United States. Using this approach, attenuation factors estimated for tropical regions where buildings are not heated throughout the year were used to develop soil vapor action levels presented in the HDOH EHE guidance.

Two USEPA vapor intrusion guidance documents were being finalized for publication at the time that the Brewer at al. (Brewer at al., 2014b.) research was published, one for vapor intrusion in general (USEPA 2015c.) and one specific to vapor intrusion associated with petroleum (USEPA 2015b). The research published by Brewer et al. (Brewer et al., 2014b.) is referenced in the USEPA petroleum vapor intrusion guidance. The research is not, however, referenced in the general vapor guidance. This was due to completion of the final review of the guidance document prior to publication of the Brewer et al. (Brewer et al., 2014b.) paper (personal communication, Kapuscinski, 2016.):

The (Brewer et al. 2014) paper… on subslab attenuation factors was published (Fall 2014) after the intra-agency vetting concluded for the (2015) OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air (OSWER Publication 9200.2-154). By contrast, the (2015) Technical Guide for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites (EPA 510-R-15-001) was prepared and revised somewhat independently.

Although publication of the USEPA vapor intrusion guidance documents postdate publication of the Brewer et al. (Brewer et al., 2014b.) research, presentation of indoor air: subslab vapor attenuation factors in the documents based on the 2012, USEPA "empirical database" should be considered invalid and not referred to for use in site-specific, vapor intrusion investigations.

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13.3 TIER 1 ENVIRONMENTAL ACTION LEVELS

Tier 1 Environmental Action Levels (Tier 1 EALs) are concentrations of contaminants in soil, soil gas and groundwater below which the contaminants are assumed to not pose a significant threat to human health or the environment. Exceeding the Tier 1 EAL does not necessarily indicate that contamination at the site poses environmental hazards. It does, however, indicate that additional evaluation is warranted. This can include additional site investigation and a more detailed evaluation of the tentatively identified environmental hazards. For example, the Tier 1 EALs incorporate conservative, risk-based exposure assumptions that may not be applicable under current site conditions and warrant a more site-specific risk assessment (see also Subsection 13.5.3). The action levels, or approved alternatives, can be used to delineate specific areas of the site that require response actions. These actions can vary, depending on the hazard present and site conditions.

A detailed discussion of the development of the Tier 1 EALs is provided in the HDOH HEER Office document *Screening for Environmental Hazards at Sites with Contaminated Soil and Groundwater* (HDOH, 2016). The EALs described in the EHE document are not intended to establish policy or regulation. Use of the document and associated EALs is optional on the part of the party responsible for investigation and cleanup of a contaminated site. Reference to updated EALs will generally not be needed at sites where final cleanup levels have already been reviewed and approved by the HEER office, including sites that have already been closed. For sites where investigation is currently underway, referral to updated EALs is recommended.

13.3.1 DEFAULT CONCEPTUAL SITE MODELS

A conceptual site model (CSM) is a comprehensive representation of site environmental conditions with respect to contaminated soil and groundwater and related environmental hazards (see Subsection 3.4.3). Four default CSMs were used to develop The Tier 1 EALs (HDOH, 2016):

1. Groundwater affected or potentially affected by the release is a current or potential drinking water resource; site located within 150m of a surface water body.
2. Groundwater affected or potentially affected by the release is a current or potential drinking water resource; site *not* located within 150m of a surface water body.
3. Groundwater affected or potentially affected by the release is *not* a current or potential drinking water resource; site located within 150m of a surface water body.
4. Groundwater affected or potentially affected by the release is *not* a current or potential drinking water resource; site *not* located within 150m of a surface water body.

Only surface water bodies that are hydraulically connected to groundwater are considered to be potentially threatened by contaminated groundwater. For the purposes of the Tier 1 EALs, it is further assumed under each default CSM that contaminated soil is exposed at the ground surface or could otherwise become exposed in the future. Using this approach to initially screen site data clears the site for unrestricted land use if Tier 1 EALs are not exceeded and avoids the need for additional investigations if site conditions change. Refer to the HDOH document *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* for additional information on site conditions assumed for development of the Tier 1 EALs (HDOH, 2016).

The default CSMs can be modified and alternative action levels developed if necessary. Alternative soil action levels for direct exposure and gross contamination hazards at commercial/industrial sites are included in Appendix 1 of the detailed EHE document (HDOH, 2016). As discussed below in Subsection 13.3.3, the EAL Surfer has been modified to allow selection of land use on a site-by-site basis. Alternative action levels for deeper soils are also provided in the guidance (e.g., >3 meters below ground surface). Be aware, however, that the use of alternative CSMs and action levels could require that formal institutional or engineered controls be imposed on the property, especially for nonpetroleum-related contamination (see Section 19). **Site data should always be initially screened using the Tier 1 EALs (or approved, alternative action level) for unrestricted (e.g., residential) land use.** If the site passes this screen then there is no need to screen the data using an alternative CSM and assumed land use.

13.3.2 COMPILATION OF ENVIRONMENTAL ACTION LEVELS

Figure 13-3 summarizes the general use of the Tier 1 EALs. Approximately 150 chemicals are listed in the EAL lookup tables (HDOH, 2016). For each chemical, an action level was compiled to address each specific environmental hazard discussed above and noted in Figure 13-2, as applicable and available.

The lowest of the individual action levels for each hazard was selected for inclusion in the summary Tier 1 EAL lookup tables. This ensures that the EALs presented in these tables are protective of all potential environmental hazards. The detailed tables used to develop the Tier 1 EALs can be used to identify the specific environmental hazards that are potentially present at the site. The EAL Surfer makes this process relatively quick and easy (see Subsection 13.3.3).

An example of the selection of Tier 1 EALs for benzene is presented in Figure 13-4 (surface soils, drinking water resource threatened, unrestricted land use desired).

For soil, the action level for leaching hazards (0.22 mg/kg) is lower than the action levels for each of the other environmental hazards. This action level is therefore selected as the Tier 1 EAL [refer to lookup tables in HDOH EAL document (HDOH, 2016)]. For groundwater, the action level for drinking water toxicity concerns drives environmental hazards and is selected as the Tier 1 EAL (5 ug/L, the primary drinking water standard).

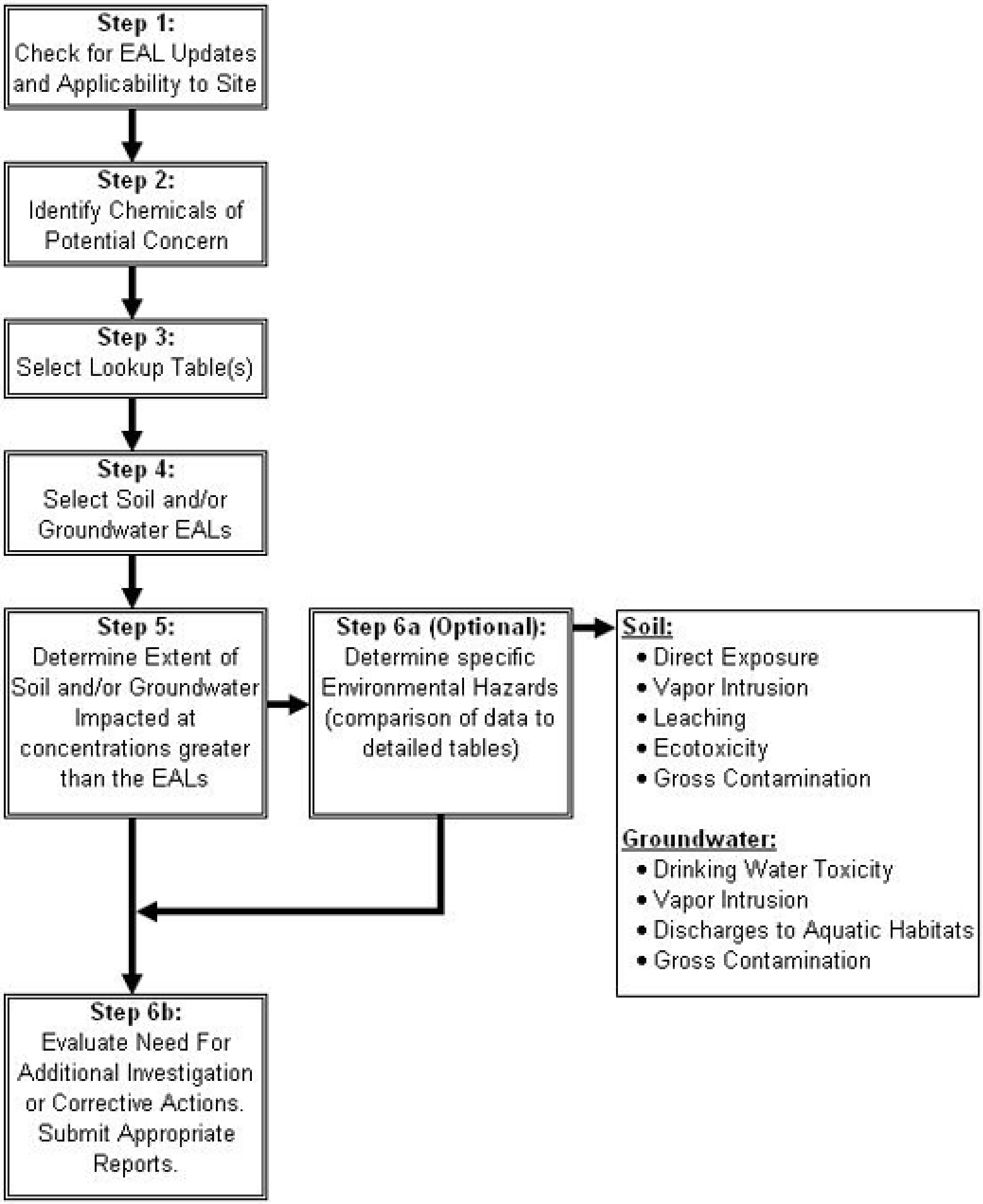

Figure 13-3 Summary of Steps for Use of Tier 1 EAL Lookup Tables.

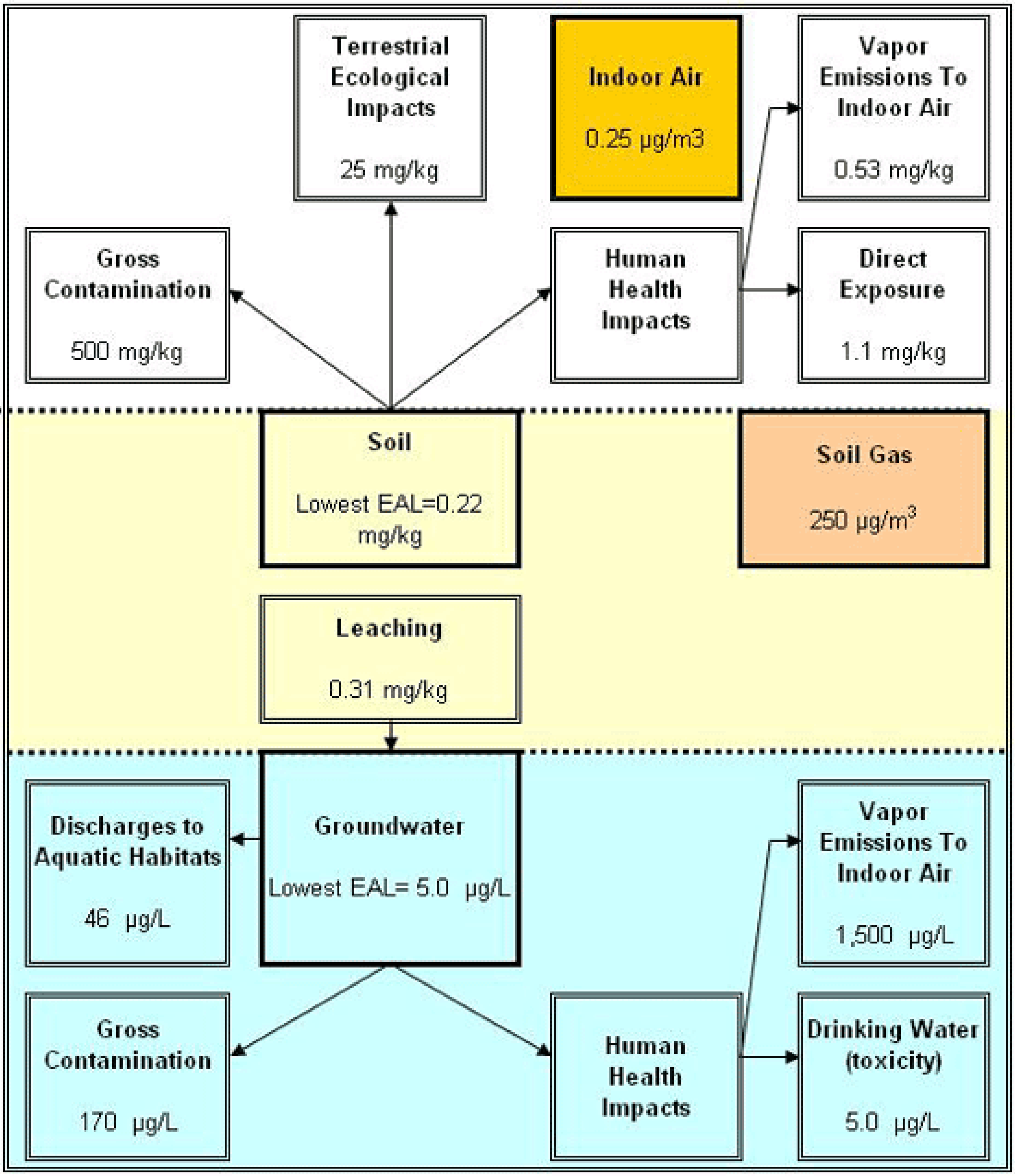

Figure 13-4. Summary of Action Levels Used to Select Tier 1 Soil and Groundwater EALs for Benzene. CSM A based on (1) groundwater is a drinking water resource, and (2) site within 150m of a surface water body. For soil and groundwater, the lowest action level for environmental hazards is selected as the final Tier 1 EAL.

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13.3.3 USE OF THE EAL SURFER

The EAL Surfer, an Excel-based version of the lookup up tables, makes use of the EALs and the identification of potential environmental hazards at contaminated sites especially easy. The EAL Surfer is available for download from the HEER Office web page:

Use of the EAL Surfer in Environmental Hazard Evaluation reports is highly recommended. To use the Surfer, simply select the appropriate site scenario information from the pull-down list (groundwater utility, distance to nearest surface water body, land use, etc.), select the target contaminant, and (optional) input the representative concentration of the contaminant in soil and/or groundwater. If included, the input concentration is compared to action levels for specific environmental hazards and the Surfer flags hazards where the action level is exceeded. A separate, summary report is generated that can be printed and included in the Environmental Hazard Evaluation report.

The 2008 version of the EAL Surfer is modified from previous versions to allow selection of commercial/industrial land use, rather than residential/unrestricted land use as assumed in the default, Tier 1 CSMs and EALs. Soil action levels for direct exposure, vapor intrusion and gross contamination hazards are higher (i.e., less stringent) than correlative action levels for residential/unrestricted land use. Soil action levels for leaching hazards are unchanged because land use does not alter the threat to groundwater. Groundwater action levels for vapor intrusion hazards are also higher for a commercial/industrial land use scenario. Action levels for other hazards are unchanged.

Example printouts of the Surfer are provided in Figures 13-5a (data input form), 13-5b (detailed environmental hazards) and 13-5c (EHE summary report). The example is based on an assumed residential land use scenario. Contaminated soil is located within three meters of the ground surface (“shallow”) and overlies groundwater that is a current or potential source of drinking water. The site is within 150 meters of a surface water body.

In the example (i.e., Figures 13-5a, 13-5b, and 13-5c), the input concentration of benzene in soil (5.1 mg/kg) causes direct exposure, vapor intrusion and leaching hazards to be flagged. Potential impacts to terrestrial ecological receptors and gross contamination are not flagged as potential hazards. The input concentration of 150 ug/L benzene in groundwater flags drinking water toxicity concerns and aquatic ecotoxicity concerns, but no other potential hazards.

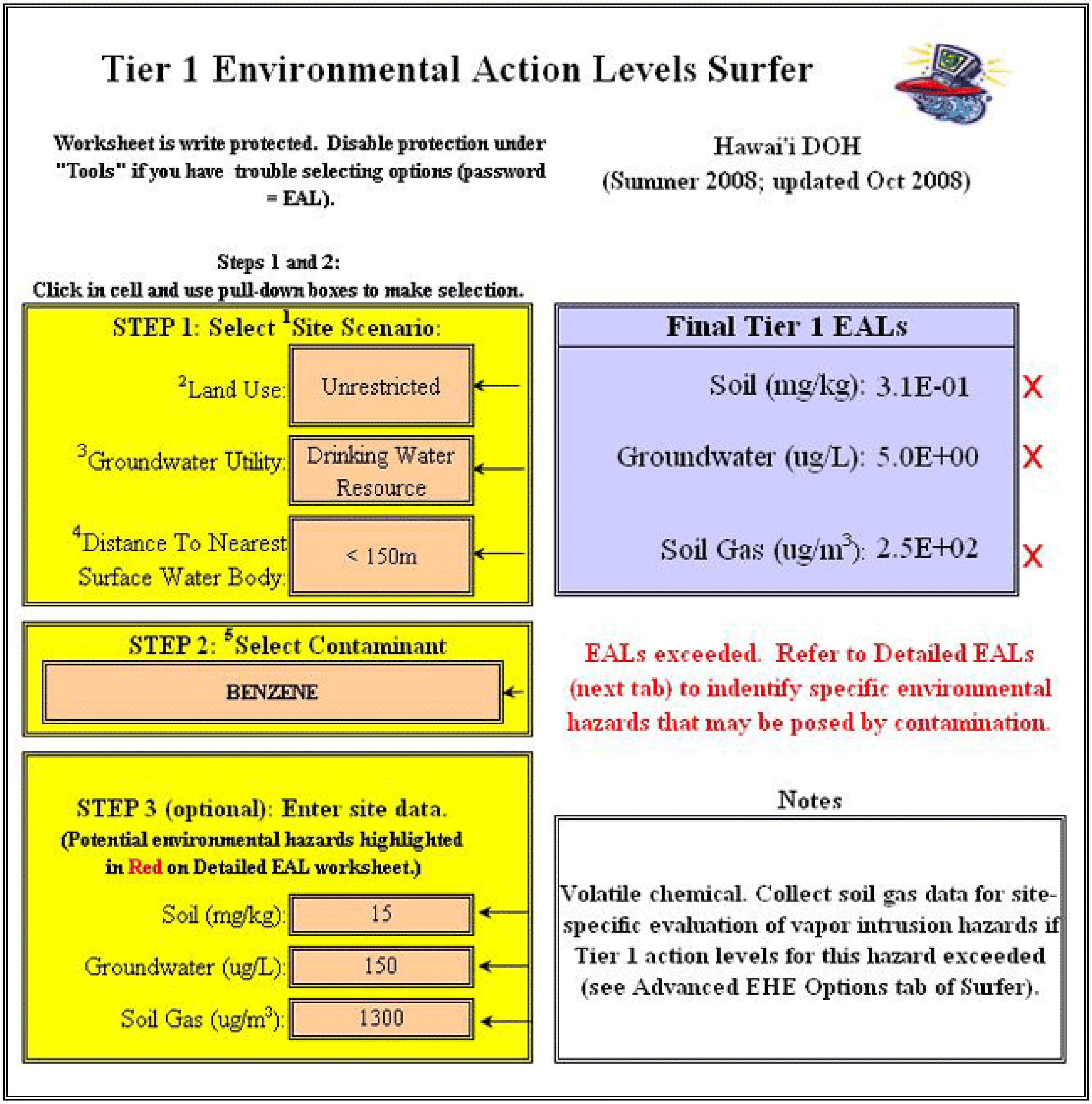
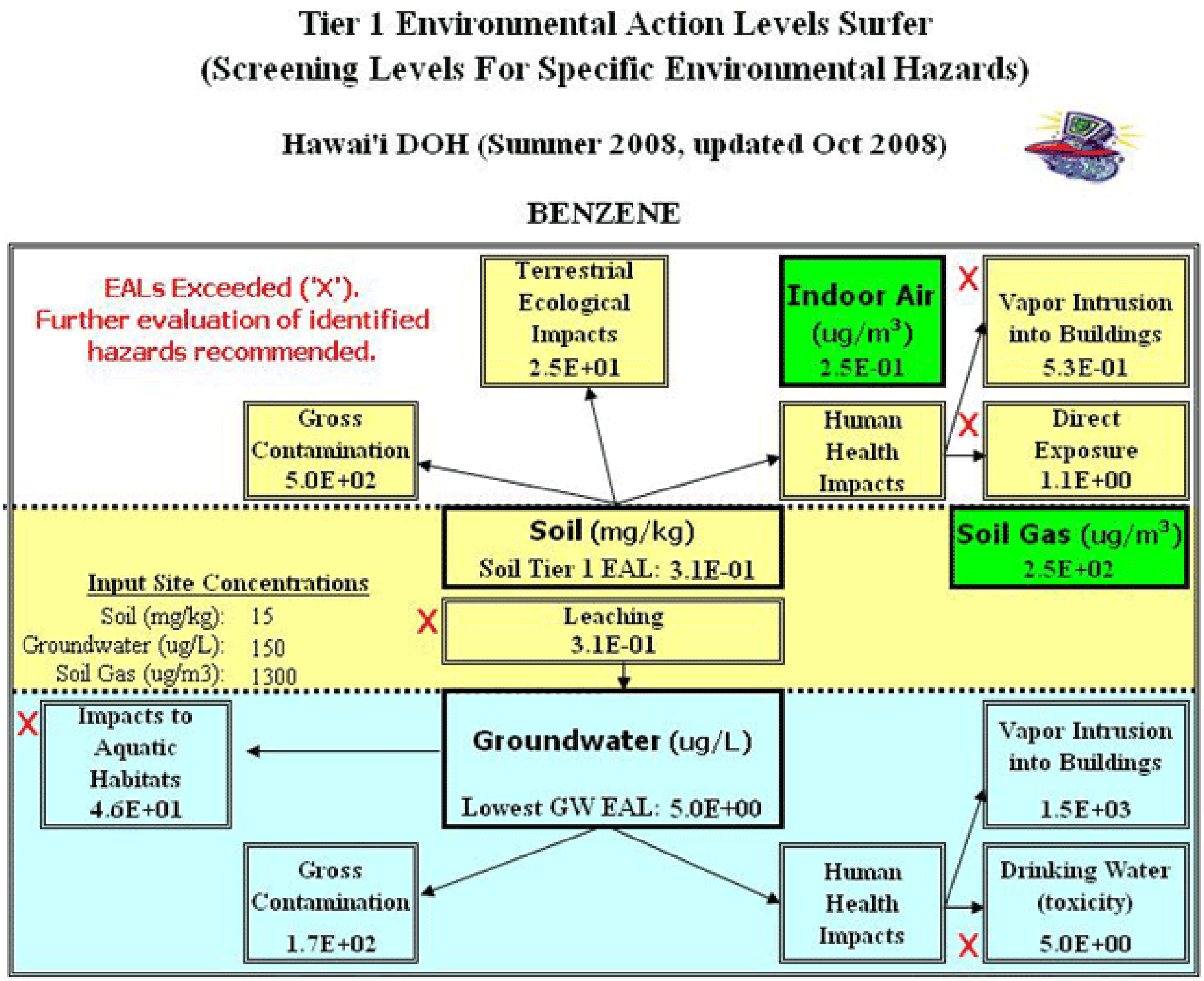


Figure 13-5a. Printout of EAL Surfer Input Page. Data used for this example was 5.1 mg/kg benzene in soil, and 150ug/L benzene in groundwater. Also, check for updates. The EAL Surfer is updated periodically and the page configurations may change.



Selected Site Scenario	
Land Use:	Unrestricted
Groundwater Utility:	Drinking Water Resource
Distance to Surface Water:	< 150m

Figure 13-5b. Printout of EAL Surfer Detailed Environmental Hazard Identification Page, Using Benzene at Noted Concentration in Soil and Groundwater as an Example. Refer also to Figure13-5a.

[1]Tier 1 EAL SURFER SUMMARY REPORT
Hawai'i DOH (Summer 2008, updated Oct 2008)

Site Name:	
Site Address:	
Site ID Number:	
Date of EAL Search:	

Selected Site Scenario	
Land Use:	Unrestricted
Depth to Impacted Soil:	Drinking Water Resource
Groundwater Utility:	< 150m

Selected Chemical of Concern:	BENZENE

Input Site Concentrations	
Soil (mg/kg):	15
Groundwater (ug/L):	150
Soil Gas (ug/m^3):	1300

Soil Environmental Hazards	Units	Tier 1 Action Level	[2]Potential Hazard?	[3]Referenced Table
Direct Exposure:	mg/kg	1.1E+00	Yes	Table I-1
Vapor Emissions To Indoor Air:	mg/kg	5.3E-01	Yes	Table C-1b
Terrestrial Ecotoxicity:	mg/kg	2.5E+01	No	Table L
Gross Contamination:	mg/kg	5.0E+02	No	Table F-2
Leaching (threat to groundwater):	mg/kg	3.1E-01	Yes	Table E-1
Background:	mg/kg	-		
Final Soil Tier 1 EAL:	mg/kg	3.1E-01		
	Basis:	Leaching		

Groundwater Environmental Hazards	Units	Tier 1 Action Level	[2]Potential Hazard?	[3]Referenced Table
Drinking Water (Toxicity):	ug/L	5.0E+00	Yes	Table D-1a
Vapor Emissions To Indoor Air:	ug/L	1.5E+03	No	Table C-1a
Aquatic Ecotoxicity:	ug/L	4.6E+01	Yes	Table D-4a
Gross Contamination:	ug/L	1.7E+02	No	Table G-1
Final Groundwater Tier 1 EAL:	ug/L	5.0E+00		
	Basis:	Drinking Water Toxicity		

Other Tier 1 EALs:	Units	EAL	[2]Potential Hazard?	[3]Referenced Table
Shallow Soil Gas:	ug/m^3	2.5E+02	Yes	Table C-2
Indoor Air:	ug/m^3	2.5E-01	-	Table C-3

Figure 13-5c. Printout of EAL Surfer EHE Summary Report, Using Benzene at Noted Concentration in Soil and Groundwater as an Example. Refer also to Figure 13-5a. This page can be printed and included in the Environmental Hazard Evaluation report. Referenced tables are from Appendix 1 of the EHE guidance (HDOH, 2016).

13.3.4 USE OF EALS IN SITE INVESTIGATIONS

One of the most basic uses of the EALs is to determine the extent of investigation needed at a site where contaminated soil or groundwater is identified. The list of Chemicals of Potential Concern (COPCs) can be quickly narrowed down by direct comparison of soil and groundwater data to the Tier 1 EALs (HDOH, 2016). Further consideration of contaminants that do not exceed Tier 1 EALs is not necessary. This assumes that existing data are representative of overall site conditions.

Delineation of the narrowed list of target COPCs to non-detect levels is often impracticable and, from a hazard evaluation standpoint, unnecessary. The investigation can be considered complete once the extent of contamination is delineated to Tier 1 EALs (or approved alternatives). As data are received during the site investigation, the EALs can be used to determine areas where the extent of contamination has been adequately identified as well as areas where additional sampling is needed. The use of field screening methods, onsite mobile labs, and/or quick turnarounds in laboratory analyses will help reduce the need for remobilizations and expedite the completion of site investigation activities.

As the site investigation is underway, a comparison of site data to action levels for specific environmental hazards can also help identify the need for alternative types of site data that will help evaluate appropriate response actions to address the contamination. For example, if arsenic is reported in soil at concentrations above the Tier 1 EAL of 20 mg/kg, then laboratory arsenic bioaccessibility tests can be used to more accurately evaluate potential direct-exposure hazards (refer to Sections 3 and Section 9). If the reported concentration of volatile contaminants in soil or groundwater exceed action levels for vapor intrusion concerns, then soil gas data can be collected to more closely evaluate this potential hazard. Incorporating these decisions in the sampling and analysis plan for the site will help expedite completion of the site investigation as well as alert responsible parties to potentially significant environmental conditions at the site.

13.3.5 USE OF EALS IN ENVIRONMENTAL HAZARD EVALUATIONS

The most important use of the HDOH Tier 1 EALs is the rapid identification of potential environmental hazards associated with contaminated soil and groundwater (refer to Subsection 3.4). With the exception of gross contamination, most of the environmental hazards noted above are not obvious in the field. An initial comparison of site data to the Tier 1 EALs will only indicate if a potential hazard is present (i.e., “yes” or “no”). If the Tier 1 EAL is exceeded, site data should be compared to the detailed action levels used to develop the Tier 1 EALs to identify the specific potential environmental hazards present. As discussed above, use of the *EAL* Surfer will significantly expedite this process (see Subsection 13.3.3).

Potential environmental hazards identified in a basic screening level *Environmental Hazard Evaluation* can be evaluated on a more site-specific basis as needed. The information gained can be used to better define the need for additional site investigation as well as develop appropriate remedial options. Approaches for more advanced or site-specific evaluation of specific environmental hazards are briefly discussed in Subsection 13.5.4.

The level of effort required for advanced evaluations can vary greatly. For example, qualitatively discounting potential hazards posed to terrestrial ecological habitats will be relatively simple at highly developed commercial or industrial sites, based on the lack of significant habitat. The collection of additional soil gas data is very useful (and strongly recommended) for more detailed evaluations of vapor intrusion concerns. The inclusion of soil gas action levels in this guidance helps expedite this evaluation. A detailed review of groundwater data can sometimes be used in place of soil action levels to better evaluate leaching and groundwater contamination concerns. In other cases, additional laboratory tests and/or use of environmental models may be required (see Subsection 13.5.4).

13.3.6 USE OF EALS IN RESPONSE ACTIONS

The Tier 1 EALs are not strict cleanup standards. In cases where the extent of contamination is minimal and time is of the essence, however, it may be more cost-effective to simply remediate soil contaminated above the Tier 1 EALs (or acceptable, alternative action levels) without further evaluation. In other cases, use of the detailed action levels to identify site-specific environmental hazards posed by the contamination will play an important role in final response actions.

For example, placing a soil cap on contaminated soil may be acceptable in some cases (e.g., direct exposure to non-volatile contaminants) and not in others (e.g., vapor intrusion or leaching hazards). Using the detailed action levels to understand the specific environmental hazards posed by contaminated groundwater is especially important. Identifying toxicity hazards and taste and odor hazards in groundwater that is currently used as a source of drinking water is obviously important. Expeditious actions to address vapor intrusion hazards posed by contaminated soil are usually warranted. In contrast, long-term monitoring may be acceptable for groundwater that poses only gross contamination hazards (e.g., toxicity-based action levels for currently unused drinking water resources not exceeded) or potential aquatic toxicity hazards if it were to migrate offsite and discharge into a body of surface water.

Long-term management will be required for sites where soil and groundwater contaminated above levels of potential concern cannot be remediated in a relatively short time frame. In such cases, the detailed action levels presented in this guidance (or acceptable alternatives) should be used to delineate areas of contaminated soil and groundwater that will require long-term management as well as the specific environmental hazards posed by the contamination under uncontrolled site conditions. Specific actions required to address these hazards should then be described in an Environmental Hazard Management Plan (EHMP). Refer to Sections 18 and Section 19 for additional details on EHMPs.

13.3.7 CHEMICALS WITH MRL THAT EXCEED EALS

Environmental Action Levels (EALs) for a number of chemicals can be below commercial laboratory Method Reporting Limits (MRLs) for a number of chemicals in groundwater. This is not generally the case for soil. As discussed in the EHE guidance, the laboratory MRL, or equivalent, should be used to screen site data (see HDOH, 2016).

Chemicals with laboratory MRLs that could exceed the HDOH EALs for groundwater are given in Table 13-2.

If the reported concentration of a chemical exceeds the MRL then the need for additional action should be discussed with the HEER office.

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Table 13-2 Chemicals with laboratory reporting limits that could be higher than HDOH Environmental Action Levels.

Groundwater	Soil
Aldrin	Bis(2-chloroethyl)ether
Benzo(a)anthracene	Bromodichloromethane
Benzo(a)pyrne	Bis(2-chloroisopropyl)ether
Benzo(b)fluorene	p-Chloroaniline
Bis(2-chloroethyl)ether	Chloroform
Bis(2-chloroisopropyl)ether	2-Chlorophenol
Boron	3-Dibromo, 1,2-chloropropane
Bromodichloromethane	Dibromochloromethane
Chlordane(Technical)	1,2-Dibromomethane
2-Chlorophenol	3,3-Dichlorobenzidine
Cobalt	1,2-Dichloroethane
Cyanide(Free)	1,4-Dioxane
Dibenzo(a,h)anthracene	Methyl tert-Butyl Ether
3-Dibromo,1,2-chloropropane	Perchlorate
Dibromochloromethane	Phenol
1,2-Dibromoethane	tert-Butyl Alcohol
3,3-Dichlorobenzidine	1,1,1,2-Tetrachloroethane
Dichlorodiphenyldichloroethane (DDD)	1,1,2,2-Tetrachloroethane
Dichlorodiphenyldichloroethylene (DDE)	
Dichlorodiphenyltrichloroethane (DDT)	
1,2-Dichloroethane	
2,4-Dichlorophenol	

1,3-Dichloropropene	
Dieldrin	
Diethylphthalate	
Dimethylphthalate	
Endosulfan	
Endrin	
Heptachlor	
Heptachlor Epoxide	
Indeno(1,2,3-cd)pyrene	
Methoxychlor	
1-Methylnaphthalene	
2-Methylnaphthalene	
Polychlorinated Biphenyls (PCBs)	
1,1,1,2-Tetrachloroethane	
1,1,2,2-Tetrachloroethane	
Toxaphene	

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13.4 CHEMICALS NOT LISTED IN LOOKUP TABLES

Soil, groundwater, soil gas and/or indoor air action levels should be developed and approved by HDOH for chemicals not listed in the current lookup tables but identified during a site investigation. A detailed discussion of the development of action levels presented in this guidance is provided in Appendix 1 of the EHE guidance (see HDOH, 2016). Preparation of the action levels should be co-ordinated with the HEER office.

An exception are petroleum compounds collectively measured under Total Petroleum Hydrocarbons (see Section 9), With the exception of the target, indicator compounds noted in Section 9, individual petroleum-related compounds that are captured and included in TPH analyses do not need to be evaluated separately in an EHE. Action levels for these compounds do not need to be developed. This includes a host of alkanes, alkenes, alkyl benzenes and other aromatics not specifically identified as target indicator compounds that could be reported separately in analytical methods for volatile organic compounds (e.g., trimethylbenzenes).

Action levels must be developed for all applicable, potential hazards (refer to Subsection 13.1; see also HDOH, 2016). **In particular, the USEPA Regional Screening Levels (RSLs, USEPA, 2012a and updates) *cannot* be used as standalone criteria for the evaluation of contaminated soil.** This is because the RSLs do not consider all potential environmental hazards posed by contaminated soil. In particular, the RSLs do not address potential vapor intrusion, leaching or gross contamination hazards and may not adequately address cumulative health risks.

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13.5 STEPS TO ENVIRONMENTAL HAZARD EVALUATION

It is important to begin to identify potential environmental hazards at a site as soon as initial soil, groundwater and other data are received. As discussed above, this is used to guide completion of the site investigation as well as to identify hazards that may require additional attention. Questions that should be asked and addressed as part of the Environmental Hazard Evaluation include:

1. Of the initial list of COPCs, which contaminants could pose potential environmental hazards under uncontrolled site conditions?
2. What are the specific environmental hazards posed by the targeted COPCs?
3. Are additional site data needed to better define the extent and magnitude of contamination or the specific environmental hazards identified?
4. Is an advanced evaluation of a specific environmental hazard warranted?
5. What is the distribution of potential environmental hazards across the site?
6. Is a response action required to address identified hazards?

These questions are discussed in more detail in the following sections. As discussed in Section 3, the initial Conceptual Site Model should be continually refined as additional data are collected and a greater understanding of site conditions is gained.

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13.5.1 IDENTIFY KEY COPCS

Preliminary COPCs are selected based on the known or assumed past use of hazardous chemicals at the site. This is an important part of the Phase I assessment of the site and the subsequent preparation of a sampling and analysis plan. For example, if gasoline was stored at the site then the target COPCs should be TPH-gasoline, benzene, toluene, ethylbenzene, and xylenes (BTEX), lead and fuel oxygenates. If the site was used to mix pesticides then the specific types of pesticides should be identified. Related contaminants such as arsenic, lead, mercury and dioxins should also be considered COPCs. Additional guidance for pesticide and petroleum contamination is provided in Section 9. Refer also to the HDOH *Screening for Environmental Hazards at Sites with Contaminated Soil and Groundwater* guidance document (HDOH, 2016).

The list of COPCs can be quickly narrowed down once initial data are obtained by a comparison of data to the Tier 1 EALs. If the representative concentration of a contaminant does not exceed the respective Tier 1 EAL, then it can be reasonably assumed the contaminant does not pose a significant environmental hazard. If the Tier 1 EAL *is* exceeded, then additional evaluation of that contaminant is warranted. Contaminants that exceed the Tier 1 EALs should continue to be considered COPCs and carried through the environmental hazard evaluation process.

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13.5.2 DETERMINE REPRESENTATIVE CONTAMINANT CONCENTRATIONS

As discussed in Sections 3 and Section 4, sites should be subdivided into individual decision units (DU) and the representative concentration of target COPCs within each DU determined. For groundwater and soil gas samples, direct reference to reported concentrations of COPCs in single monitoring wells or soil gas collection points is appropriate.

For soil, the use of *Multi-increment* sample data to determine representative contaminant concentrations is preferred over discrete sample or judgmental sample data (see Section 4). *Multi-increment* samples provide better coverage of DUs and better estimates of representative contaminant concentrations in comparison to discrete sample data, especially in cases where only a limited number of discrete sample points (e.g., <30) are located within a target DU. *Multi-increment* is a registered trademark of Envirostat, Inc.

Discrete soil sample data can also inject an unnecessary distraction into the site investigation process due to a tendency to focus on “maximum” contaminant concentrations reported at a single sample point location. Identification of the maximum concentration of a contaminant at any given point within a DU is not an objective of the site investigation or environmental hazard evaluation process. As discussed in Section 4, the concentration of a contaminant at any given sample point location in itself has little importance. This is because direct exposure or other potential environmental hazards must be evaluated for the DU as a whole, rather than at any given point within the DU. In typical environmental contaminant evaluations, the question is:

“What is the *representative* contaminant concentration across the DU as a whole?” not “What is the *maximum* contaminant concentration across the DU as a whole?”

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13.5.3 IDENTIFY POTENTIAL ENVIRONMENTAL HAZARDS

If the representative concentration of a contaminant is verified to exceed Tier 1 EALs then the specific environmental hazard(s) posed by the contaminant should be identified. A detailed, site-specific evaluation of each possible environmental hazard on a site-specific basis would be an arduous and time-consuming task. Fortunately, this level of effort will rarely be necessary. A simple comparison of site data to the detailed action levels used to develop the Tier 1 EALs offers a relatively rapid and cost effective alternative. As discussed in Subsection 13.3.3, use of the EAL Surfer to identify specific environmental hazards makes this process relatively simple and is highly recommended.

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13.5.4 ADVANCED EVALUATION OF ENVIRONMENTAL HAZARDS

Potential environmental hazards flagged by comparison of site data to Tier 1 EALs (or approved alternative action levels) may or may not exist at the site. The Tier 1 EALs assume uncontrolled site conditions, with the potential for contaminated soil to be exposed at the surface at some point in the future under a residential land use scenario. The models used to develop the soil action levels assume a fresh release and maximum contaminant mobility. Screening soil data at this level allows unrestricted use of the property. Actual site conditions could differ and contaminants could pose a much lower threat to human health and the environment than a simple screening level evaluation might imply. If warranted by potential cleanup costs or other factors (including requirement by the HEER Office), a more advanced and site-specific evaluation of targeted hazards can be carried out.

Advanced approaches for evaluation of environmental hazards discussed earlier are presented in the HDOH guidance document *Screening for Environmental Hazards at Sites with Contaminated Soil and Groundwater* ["EHE guidance" (HDOH, 2016)]. A summary of commonly used approaches is provided in Tables 13-3 and 13-4.

The need to carry out more advanced evaluations of tentatively identified environmental hazards must be assessed on a case-by-case basis. Exceeding action levels for specific hazards does not necessarily indicate the contamination poses a significant threat to human health and the environment, only that additional evaluation is warranted (see Subsection 13.3). In many cases the most cost-effective action to address a tentatively identified environmental hazard is to simply remove all contamination that exceeds Tier 1 EALs (e.g., excavation and disposal of a small area of lead-contaminated soil). In cases where cleanup costs could be substantial or full cleanup is otherwise not technically feasible, a more detailed evaluation of tentatively identified environmental hazards may be warranted. For petroleum-related contamination in particular, soil gas data often indicate a much lower vapor intrusion hazard than predicted by simple comparison of soil or groundwater data to HEER Office action levels. The additional data could negate the need for remedial actions at some sites to address this hazard. In other cases, soil gas data can help identify the presence of contamination that was not detected in earlier soil and groundwater sample collection.

Preparing a traditional human health risk assessment or ecological risk assessment as described in the following sections *does not* fulfill the need to prepare an initial *Environmental Hazard Evaluation*. As discussed in Subsection 13.6, a traditional risk assessment focuses on toxicological risks associated with direct exposure to contaminated soil, groundwater, or air. While this is important, direct exposure is only *one* of several potential environmental hazards that must be addressed in a more comprehensive Environmental Hazard Evaluation. Action levels specifically developed to screen for potential direct exposure concerns are incorporated in the Tier 1 EALs. Exceeding Tier 1 EALs does not necessarily indicate that the contamination does in fact pose direct-exposure hazards, only that potential risks to human health need to be considered in subsequent actions at the site. This could include preparing a more detailed human health risk assessment (see Subsection 13.6).

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Table 13-3 Commonly Used Approaches for Evaluating Environmental Hazards in Groundwater

Environmental Hazard	Example Site-Specific Evaluation Approaches
Contamination of drinking water resources	· Identification and monitoring of nearby, groundwater supply wells and guard wells· Long-term monitoring of groundwater to evaluate plume migration potential · Use of groundwater plume fate & transport models in combination with long-term monitoring to evaluate plume migration potential
Vapor Intrusion	· Collection of soil gas data (strongly recommended) and subsequent evaluation of risk to human health (site-specific vapor intrusion model)
Impact to Aquatic Habitats	· Use of groundwater data to evaluate plume expansion and migration over time · Use of fate and transport models to predict long-term migration potential of groundwater contaminant plumes · Preparation of a site-specific, ecological risk assessment, which can include aquatic bioassay testing, an evaluation of species diversity and/or sediment studies
Gross contamination	· Check groundwater for free product · Check discharge areas for sheen and other gross contamination concerns

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Table 13-4 Commonly Used Approaches for Evaluating Environmental Hazards in Soil

Environmental Hazard	Example Site-Specific Evaluation Approaches
Direct Exposure	· Use of *Multi-increment* sample data to evaluate direct exposure concerns in targeted decision units · Use of HDOH Tier 2 Direct Exposure Spreadsheet to calculate alternative action levels (available from HEER Office web page) · Use of laboratory arsenic bioaccessibility tests to better evaluate arsenic toxicity · Preparation of a site-specific human health risk assessment that considers engineered and institutional controls to eliminate or minimize exposure pathways, alternative exposure assumptions, alternative target risks, etc.
Vapor Intrusion	· Collection of soil gas data (strongly recommended) and subsequent evaluation of risk to human health risk (site-specific vapor intrusion model)

Environmental Hazard	**Example Site-Specific Evaluation Approaches**
Leaching	· Collection of groundwater data · Use of HDOH laboratory batch test guidance to evaluate contaminant mobility and estimate concentrations in source area leachate
Impacts to terrestrial habitats	· Field inspection to determine the presence or absence of potentially significant terrestrial ecological habits · Preparation of a detailed ecological risk assessment.
Gross contamination	· Field inspection of petroleum-contaminated soil to evaluate potential gross contamination concerns (especially in existing or planned residential areas)

Additional guidance is provided in the HDOH EHE guidance document (HDOH, 2016).

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13.5.5 COMPLETE THE SITE INVESTIGATION

The identification of potential environmental hazard(s) and completion of the site investigation is an iterative process. Basic site investigation activities can be considered complete when the vertical and lateral extent of contamination above Tier 1 EALs (or acceptable alternatives) is determined. In some cases (e.g., investigation of commercial/industrial areas with land use restrictions), the delineation of contamination to higher action levels will be acceptable. The need for additional site data to complete the investigation should be continually reviewed as initial data is screened for potential environmental hazards.

For example, if direct exposure to contaminated soil is flagged in the EAL Surfer as a potential hazard, then site data should be reviewed to ensure that the limits of contamination are adequately identified. Estimating representative contaminant concentrations across exposure areas (e.g., residential yards, commercial lots) rather than more specific areas is generally acceptable. This is because it is assumed a person would have equal access to all parts of the exposure area (i.e., decision unit), not just the contaminated areas. For large, industrial complexes, the property may need to be divided into smaller decision units based on specific exposure areas (e.g., specific work areas at an industrial site). The use of *Multi-increment*sampling to better estimate exposure point concentrations for specific exposure areas should be considered (see Section 4). The collection of arsenic bioaccessibility data for arsenic-contaminated soil is recommended when the concentration of total arsenic exceeds the Tier 1 EAL of 20 mg/kg. This is used to better evaluate direct exposure concerns.

If soil leaching hazards are identified then specific spill areas should be identified and treated as separate decision units. This is because the spill area, not the site as a whole, is the target where the “receptor” of concern is the groundwater directly underneath the contaminated soil. If Tier 1 soil action levels for leaching concerns are exceeded, then batch test data should be collected for the target contaminants and a more advanced evaluation of leaching concerns carried out. Keep in mind that soil data are not necessarily good indicators of potential groundwater contamination. This is especially true for chlorinated solvents. Releases of wastewater contaminated with solvents may not leave an identifiable smear zone in vadose-zone soil due to the low sorptive capacity of the solvent compounds, even though the release results in significant contamination of groundwater.

Soil or groundwater data flagged for potential vapor intrusion almost always indicates that soil gas samples should be collected at the site. The model used to develop the soil and groundwater actions levels for vapor intrusion hazards estimates the concentration of a volatile contaminant in shallow soil gas based on assumed chemical and soil properties. The models are considered to be conservative, especially for highly biodegradable chemicals like TPH and BTEX. Active soil gas data (e.g., collected in a summa canister) are much more reliable for evaluation of this hazard. The collection of methane data is also useful at sites with heavy petroleum contamination to address the potential for explosion hazards, especially where confined spaces are present or may occur after redevelopment.

The results of the site investigation should be summarized on to-scale maps and, as needed, cross sections of the site that clearly delineate the lateral and vertical extent of contamination above Tier 1 EALs (or approved alternative action levels). The same maps can be used to identify areas of specific environmental hazards and assist in development of appropriate response actions, as discussed below. A recommended format and content requirements for site investigation reports is presented in Section 18

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13.5.6 PREPARE ENVIRONMENTAL HAZARD MAPS

Documentation of the distribution of environmental hazards across the site is an important step in the conceptual site model. Examples of issues to consider include: 1) What areas of the site pose potential direct exposure or vapor intrusion hazards? 2) What areas of the site pose potential leaching hazards? and 3) In what areas will grossly contaminated soil likely be encountered during future subsurface activities? Understanding the site in terms of environmental hazards rather than just contaminant concentrations is important because this serves as the basis for cleanup as well as long-term management plans. The most appropriate response action can vary, depending on the environmental hazards posed by the targeted contaminants.

Although not always needed or required, post-cleanup “as built” *environmental hazard maps* that clearly depict the extent and nature of environmental hazards at a site can be very useful. As discussed in the previous sections, this can be accomplished by comparison of site data to HEER Office action levels (or acceptable alternatives) for targeted hazards. Maps that summarize the extent and magnitude of contamination can be converted to environmental hazard maps by basing contaminant isoconcentration contours on action levels for specific hazards.

Example environmental hazard maps are provided in Figures 13-6 and 13-7.

In Figure 13-6, soil contaminated with dioxins and arsenic poses direct exposure hazards across a large portion of the site. Soil contaminated with chlorinated herbicides (e.g., ametryn, atrazine, diuron, etc.) in a smaller area of the site poses an additional leaching hazard. In a third area, soil contaminated with chlorinated solvents poses vapor intrusion hazard, a direct exposure hazard and a leaching hazard. In a fourth area, soil contaminated with heavy petroleum poses only gross contamination concerns. Note that highly toxic and mobile contaminants often pose a combination of several environmental hazards, including vapor intrusion, direct exposure and leaching (e.g., PCE).

The environmental hazard map in Figure 13-6 can now be used to guide selection of the most appropriate remedial alternative. Complete removal of contamination is obviously preferable. Assuming that this is not achievable for the example, a well-managed soil cap can be adequate to eliminate direct exposure hazards. Areas that pose a leaching hazard and cannot be cleaned up in a relatively short time frame will, in contrast, require some type of impermeable cap. Subslab vapor mitigation systems will be required for new buildings placed within the vapor intrusion hazard area. Indoor air studies may be needed for existing buildings located in this area.

Documenting where grossly contaminated soil and groundwater will be left in place at a site is also important (e.g., Figure 13-7). Gross contamination hazards often drive the cleanup of contaminated soil and groundwater, not direct exposure or even leaching hazards. Over time, grossly contaminated soil and groundwater can generate methane and related explosive hazards. Although the contamination may not pose environmental hazards under current site conditions, the unexpected discovery of grossly contaminated soil and groundwater during subsurface construction or utility activities can result in significant delays and project costs. Foreseeing and documenting these concerns in an Environmental Hazard Management Plan is important (see Sections 18 and Section 19).

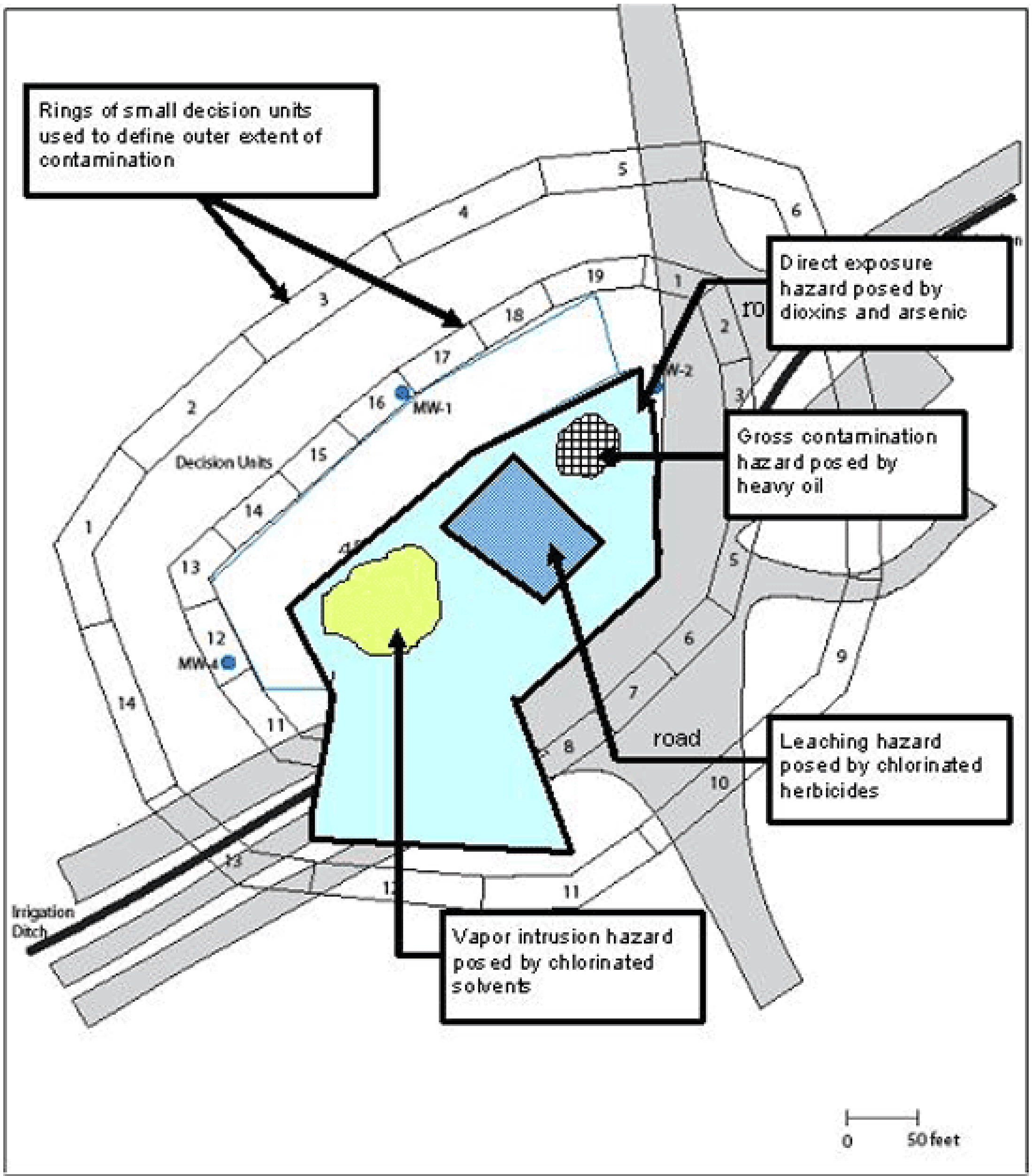

Figure 13-6. Environmental Hazard Map for Hypothetical Site with Soil Contamination. Hypothetical hazards include pesticides, dioxin, arsenic, solvents and heavy oil. Areas delineated by comparison of site data to HDOH action levels for the noted hazard (or approved alternatives). Remedial options could vary with respect to the specific environmental hazard(s) posed in a given area of the site including capping, vapor mitigation systems, offsite disposal, etc. (see text).

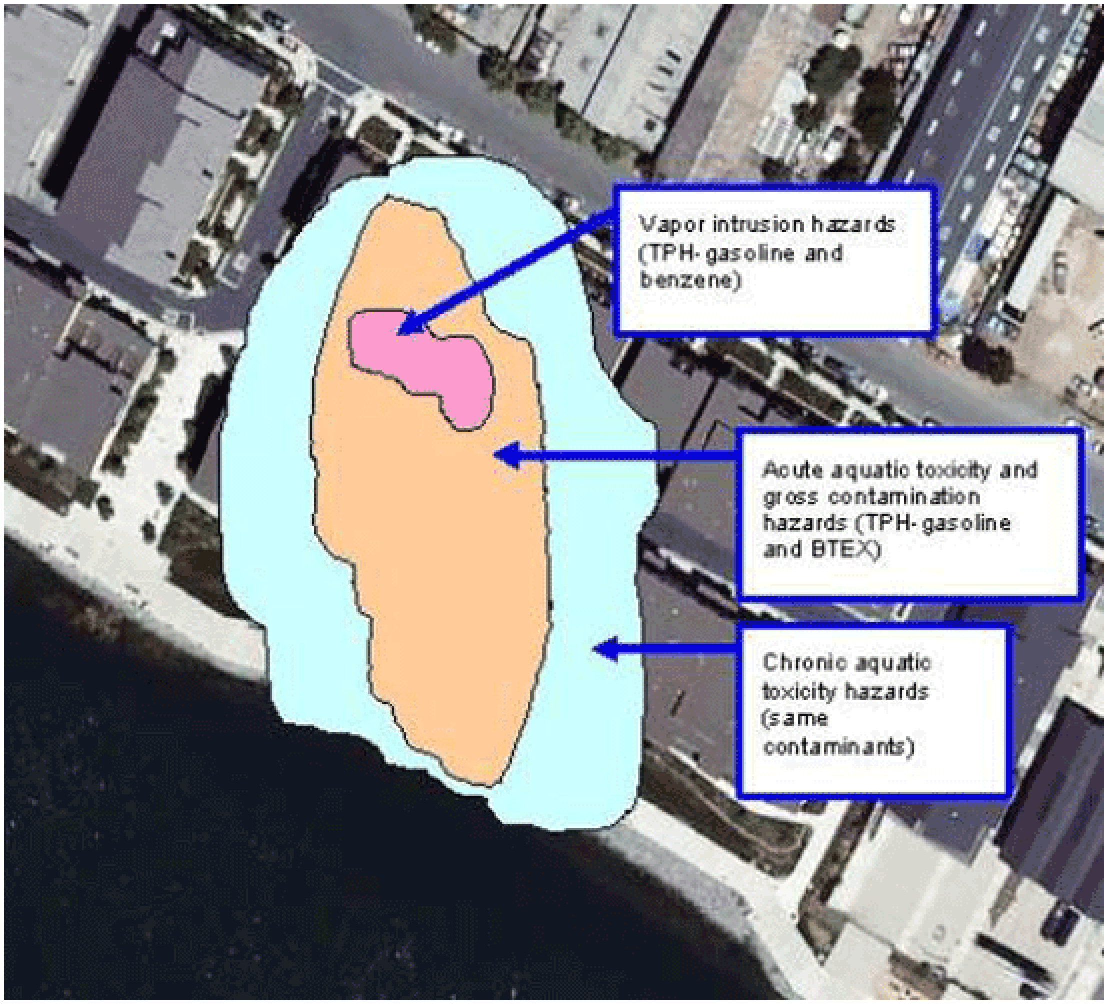

Figure 13-7. Environmental Hazard Map for Hypothetical Site with Groundwater Contamination. Hypothetical site contaminated with petroleum. Areas delineated by comparison of site data to soil screening levels for the noted hazard. Aggressive remediation should focus on removal of vapor intrusion hazard so property can be redeveloped. Aggressive remediation of groundwater that poses acute aquatic toxicity hazards and gross contamination (odors, sheens) within 50 meters of the shoreline is also recommended. Long-term monitoring of remaining groundwater contamination required (see text).

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13.5.7 RECOMMENDED FOLLOW-UP ACTIONS

Based on the results of the Environmental Hazard Evaluation, provide recommendations for additional actions at the site. This could include additional fieldwork, additional analyses of existing samples, further evaluation of targeted environmental hazards, evaluation of remedial alternatives, preparation of an Environmental Hazard Management Plan, etc. If all contamination above Tier 1 EALs (or approved alternatives) is removed or if otherwise warranted by site conditions, then a recommendation of no further action should be made. The most appropriate response to address environmental hazards at contaminated sites depends on a number of site-specific factors, including the presence or absence of hazards under current conditions, planned future site use, the regulatory acceptability and cost-benefit of immediate cleanup as opposed to the use of engineered and institutional controls, natural attenuation of contaminants over time, etc. When practicable, full cleanup of contaminated soil and groundwater to permit future, unrestricted use of the property is desirable. A detailed discussion of site closure considerations is presented in Section 19.

When full cleanup is not feasible, the extent and magnitude of remaining contamination must be summarized and the potential environmental hazards posed by the contamination under uncontrolled conditions clearly described. The need for institutional and engineered controls must then be evaluated. This could include restrictions on future use of the property, installation of vapor mitigation systems under buildings, capping of contaminated soil to prevent exposure or leaching, long-term monitoring of groundwater, etc. These actions must be described in a site-specific EHMP. The preparation of an EHMP is discussed in more detail in Sections 18 and Section 19.

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13.6 HUMAN HEALTH RISK ASSESSMENTS

In a very limited number cases a traditional Human Health Risk Assessment (HHRA) will be needed to more fully evaluate and document direct exposure concerns identified in the Environmental Hazard Evaluation (HDOH, 2016). An HHRA justifies and employs alternative models and assumptions to develop site-specific screening or final cleanup levels or quantitatively evaluate actual risk posed to human receptors. This type of Advanced Environmental Hazard Evaluation typically follows methodologies, assumptions, and risk assessment models for traditional, detailed HHRAs. Portions of the Tier 1 models still may be retained for some components of the Advanced Environmental Hazard Evaluation.

A HHRA can be described as a scientific process used to estimate the probability of adverse health effects resulting from human exposure to hazardous substances. In 1986, the USEPA established risk assessment guidelines to provide consistency and technical support between the USEPA and other regulatory agencies. The HEER Office recommends that HHRAs be prepared following USEPA risk assessment guidelines. The fundamentals of USEPA's HHRA methodology are presented in *Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A)* (USEPA, 1989e).

A HHRA applies four evaluation components as the basis for characterizing potential health risks posed to current and/or potential future receptors at a site (USEPA, 1989e), as shown in Table 13-5.

Table 13-5 Evaluation Components for Characterizing Potential Health Risks to Current and/or Potential Future Receptors

1.	**Data Usability Evaluation/ Selection of COPCs** • Collate the site investigation data • Evaluate the data	**3.**	**Toxicity Assessment** • Identify toxicity values for the COPCs

	• Select COPCs		
2.	**Exposure Assessment** • Identify exposure scenario • Identify exposure pathways • Identify exposure factors for receptors • Quantify exposure point concentrations • Calculate exposure for each COPC/medium/pathway combination	4.	**Risk Characterization** • Calculate the cancer risks and non-cancer hazard indices. • Summarize the site risks by COPC and medium for the receptors, exposure scenarios, and exposure pathways • Identify key uncertainties and evaluate their potential impacts on the results.

A summary of the basic components of a human heath risk assessment is provided below. Detailed guidance for preparing a HHRA is beyond the scope of this Section. Refer to the references provided at the end of this section for additional guidance and information.

It is vital to ensure that all potential environmental hazards have been considered at a site when conducting a site-specific human health risk assessment. Environmental Hazard Evaluations that only consider risk to human health (e.g., direct exposure to contaminated soil) will *not* be considered acceptable by the HEER Office.

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13.6.1 COMPONENTS OF HUMAN HEALTH RISK ASSESSMENT

The components of a traditional HHRA are briefly reviewed below.

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13.6.1.1 DATA USABILITY EVALUATION/SELECTION OF COPCS

Most of this task is completed during site investigation and presented in the site investigation report. Elements of data assessment are presented in Subsection 3.9. A preliminary list of COPCs is developed in the scoping process during site investigation planning (see Subsection 3.3). The COPCs are refined as the site investigation objectives are developed and the site investigation data are acquired (see Section 3).

To prepare a HHRA, it may be necessary to collate data from several site investigations and assess the collective data. Comparing the collated data to Tier 1 EALs is a good starting point for refining and finalizing the list of COPCs. It is important to remember that COPCs may be uniquely selected for individual decision units (see Subsection 3.6). In addition, COPCs may be uniquely selected for each environmental medium (e.g., COPCs for soil may be different that the COPCs for groundwater). The identified list of COPCs will be the focus of the HHRA.

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13.6.1.2 EXPOSURE ASSESSMENT

Exposure scenarios, exposure pathways, and exposure factors for receptors are identified, exposure point concentrations quantified, and exposures calculated for each COPC/medium/pathway combination in the Exposure Assessment. The statistical evaluation of soil data to estimate representative contaminant concentrations within decision units (including exposure point concentrations for evaluation of direct-exposure hazards) is discussed in Section 4. The average concentration of exposure over the target exposure duration is used for estimation of risk.

Land use is a critical element in developing exposure scenarios because it determines potential receptor populations. Land use assumptions are based on a factual understanding of site-specific conditions and reasonably anticipated future use. Discussions with land owners and local land use planning offices are helpful in determining future land use. Typical land uses to consider include residential and commercial/industrial.

An exposure pathway describes the course that a chemical takes from a source to a receptor. Potential exposures are evaluated by considering the following four factors:

- A source of potentially hazardous substances
- A contaminated media, such as soil
- An exposure or contact point with the contaminated medium
- An exposure route for chemical intake by a receptor

An exposure pathway is considered complete when it has all four factors. Designation of an exposure pathway as complete indicates that human exposure is possible, but does not necessarily mean that exposure will occur nor that exposure will occur at the levels estimated in the HHRA. When any one of the factors is missing in the pathway, it is considered incomplete. Incomplete exposure pathways do not pose a health hazard and are not evaluated. The key step in analyzing exposure pathways is to determine whether there are any plausible routes of human exposure to chemicals detected at the site.

The hypothetical receptor that is typically evaluated in each exposure scenario is assumed to have a reasonable maximum exposure (RME) by any potential exposure route. The RME, as defined by the USEPA (USEPA, 1989e), is the “highest exposure that is reasonably expected to occur” and is intended to best represent “a conservative exposure estimate that is within the range of possible exposures.” The assumption of exposure represents a conservative approach. This approach is recommended by regulatory risk assessment guidance in order to make the health risk assessment sufficiently protective of potential receptors.

Exposure factors, including exposure point concentrations for receptors are necessary to quantify exposures for each COPC/medium/pathway combination. Exposure factors are available in *Exposure Factors Handbook* (USEPA, 1997e), *Soil Screening Guidance: Technical Background Document* (USEPA 1996b), and *Supplemental Guidance for Developing Soil Screening Levels for*

Superfund Sites (USEPA, 2002e), among other sources. An exposure point concentration is a reasonable estimate of the concentration likely to be contacted over time by potential receptors (USEPA, 1989e). A discussion of approaches to determine average contaminant concentrations for exposure areas or decision units is presented in Sections 3 and Section 4 .

The final step in the exposure assessment is quantifying the *Average Daily Intake* of COPCs for the identified potential receptors in the exposure scenarios. The daily intake equations are available in *Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A)* (USEPA, 1989e).

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13.6.1.3 TOXICITY ASSESSMENT

The purpose of the Toxicity Assessment is to weigh available evidence regarding the potential for the COPCs to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a COPC and the increased likelihood and/or severity of adverse effects (USEPA, 1989e). Because the USEPA has established values for the toxicity of most typically encountered COPCs, the toxicity assessment generally consists of locating and collating toxicity information and combining it with the exposure assessment information to calculate human health risks.

A cancer slope factor is a numerical estimate of potency of a chemical that is multiplied by the Lifetime Average Daily Intake to give a probability of an individual developing cancer over a lifetime. A reference dose is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subgroups, that is likely to be without an appreciable risk of deleterious effects during a portion of a lifetime (USEPA, 1989e).

Refer to Appendix 1 of the HDOH EHE guidance for a summary of toxicity factors selected for development of environmental action levels. Except as noted, the toxicity factors for the EALs reflect those used for USEPA Regional Screening Levels guidance (USEPA, 2012).

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13.6.1.4 RISK CHARACTERIZATION

For complete pathways, risk characterization combines the Exposure Assessment and Toxicity Assessment to produce quantitative estimates of potential health risks associated with the COPCs.

For carcinogens, cancer risks are calculated according to the following equation (USEPA, 1989e):

Incremental Lifetime Cancer Risk = Lifetime Average Daily Intake x Cancer Slope Factor

For non-carcinogens, hazard quotients are calculated according to the following equation (USEPA, 1989e):

Hazard Quotient = Average Daily Intake / Reference Dose

Incremental lifetime cancer risk probabilities may be compared to the USEPA acceptable risk levels. The USEPA has established a potentially acceptable range of 10^{-4} to 10^{-6} for lifetime cancer risk (USEPA, 1989e, 1991b). Remediation or risk management is almost always warranted at sites where the estimated cancer risk exceeds 10^{-4}. For sites where the estimated risk is between 10^{-4} and 10^{-6}, the need for active remediation or risk management is evaluated on a site-specific basis (i.e., risks within this range are “potentially acceptable”, depending on site-specific considerations) (USEPA, 1991b). It should be noted that the calculated risk values are upper-bound estimates of excess cancer risk potentially arising from lifetime exposure to the chemical in question. A number of assumptions have been made in the derivation of the values, many of which are likely to overestimate exposure and toxicity. The actual incidence of cancer is likely to be lower than these estimates and may be zero.

The non-cancer hazard index is based on a comparison of the estimated site-related dose to the EPA acceptable dose. A hazard index of less than or equal to one indicates no potential for noncancer health hazard (USEPA, 2001c).

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13.6.2 REPRESENTATIVE CONTAMINANT CONCENTRATIONS

The concentration of a chemical reported for an Exposure Area Decision Unit (Subsection 3.4.2) based on Multi Increment sample data (Subsection 4.2) is used to evaluate the long-term, average exposure of residents or workers “receptors” to the chemical as part of a human health risk assessment. This was referred to as the “exposure point concentration” in past guidance (USEPA 1989e). Exposure “area” concentration is more precise of the intent of the data, however. Receptors are assumed to have random contact with soil within the targeted exposure area for a fixed number of days (“exposure frequency”) over a fixed number of years (“exposure duration”). The HDOH EALs for direct-exposure risks directly incorporate these exposure assumptions and represent the maximum concentration of the chemical for a given exposure area that does not pose a significant risk to users of the property. If this concentration is exceeded then additional evaluation is warranted, as described in this section.

The use of Multi Increment sample data is strongly recommended for estimation of exposure area concentrations. Early USEPA guidance relies on statistical tests for discrete sample data sets to estimate an exposure area concentration for a targeted chemical. Field research described in Subsection 4.1 of this guidance document point out the limitations of this approach and the inability to test the precision of estimated exposure area concentrations based on a single set of discrete soil samples. Multiple sets of discrete soil samples (minimum three) would be required to accomplish this. Uncertainty with respect to the representativeness of discrete sample data in terms of sample collection methods, minimum mass requirements under sampling theory and the lack of a systematic approach to laboratory processing further limit the reliability of discrete sample data in risk assessments. Proposals to use discrete sample data as part of a risk assessment should be discussed with the HEER Office. The collection of Multi Increment sample data to confirm initial conclusions based on discrete sample data will likely be required for high-risk areas.

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13.6.3 LEAD RISK ASSESSMENTS

Special considerations must be made to conduct a human health risk assessment for sites at which lead is a COPC. For lead risk assessments, the EPA currently recommends two models to assess exposure, depending on the age of the receptor population. For children, exposure assessments should be performed using the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) (USEPA, 1994b). For adults, EPA's 1996 adult interim guidance should be used – the "Adult Lead Model" (USEPA, 1996e). These models are available for download free-of-charge from the USEPA web site.

Both models take into account intake and uptake components of lead exposure, allow the user to input site-specific data (exposure frequency, sources of lead, as well as others), and predict potential upper-bound blood lead concentrations. Predicted blood lead values provide one indication of the associated lead exposure for both current and potential future populations (USEPA, 2002, USEPA, 2002i).

USEPA guidance for lead-contaminated soil calls for the comparison of lead concentrations in the <250 micron soil fraction to action levels (USEPA, 2000e). The fine soil fraction is considered to be the particle size fraction most likely to stick to hands and, thus, potentially be incidentally ingested. This guidance also call for the use of the %lt;250 micron soil fraction in bioaccessibility tests (USEPA, 2000e). This also applies for bioaccessibility tests carried out on arsenic-contaminated soils. Concurrent data for the <2mm soil fraction can also be very useful in determining the distribution of lead (and arsenic) in the soil.

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13.6.4 TARGET RISKS FOR PARKLANDS

In terms of human health risk assessment, parks and similar public recreational areas should be treated like residential backyards and indeed they serve this function in many densely populated areas of Hawai'i (i.e., assumed residential exposure, screening level target excess cancer risk of 10^{-6} and target hazard index of 1.0). A purely toxicity-based, recreational-use exposure scenario could suggest that substantially higher concentrations of contaminants could be left in place at the site and not pose a threat to human health. This is because of the reduced exposure frequency and duration (e.g., 100 days per year for ten years) assumed in the models. Cleanup levels based on such scenarios can be higher (less stringent) than levels that would be allowed for commercial/industrial properties. This is counterintuitive to the intention of setting aside land for public use and puts an inherent public use restriction on the property (i.e., visitation and use limited to the assumed exposure frequency and duration).

The use of public parks should be unrestricted. Placing restrictions on the use of public parks due to contamination concerns would quite likely not be acceptable to the general public, one of the tenants required for consideration of final site remedial actions. Public parks are also frequented by children, young mothers, elderly people and other groups of people with potentially elevated sensitivities to environmental contaminants. Long-term, future uses of such properties are also difficult to predict.

In some cases, remediation of proposed parklands to unrestricted land-use standards may not be technically or economically practicable. This should be evaluated on a site-specific basis and receive approval from the overseeing regulatory agency as well as private and public stakeholders. In such cases, the appropriateness of allowing unrestricted access to the area should be carefully evaluated. This could include the need to impose access restrictions on the property (i.e., based on the exposure assumptions used in the risk assessment) and/or cap impacted soils with a minimal amount of clean fill. It may also be prudent to post signs at the property entrance that warn of potential health hazards (refer also to HDOH, 2016).

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13.6.5 REFERENCES FOR HHRAS

Potentially useful reference documents for preparation of HHRAs include the following:

- Superfund Exposure Assessment Manual (USEPA, 1988c)
- Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A) (USEPA, 1989e)
- Technical Support Document: Parameters and Equations Used in the Integrated Exposure Uptake Biokinetic Model for Lead in Children (USEPA, 1994b)
- Preliminary Endangerment Assessment Guidance Manual (CalEPA, 1994)
- Standard Provisional Guide for Risk-Based Corrective Action (ASTM, 2004b)
- Superfund Soil Screening Guidance: Technical Background Document (USEPA, 1996b)
- Supplemental Guidance For Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities (CalEPA, 1996b)
- Exposure Factors Handbook (USEPA, 1997e)
- Health Effects Summary Tables (USEPA, 1997)
- Assessing the Significance of Subsurface Contaminant Vapor Migration to Enclosed Spaces (Johnson et. al, 1998)
- Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA, 2002e)
- USEPA Regional Screening Levels: (USEPA, 2012).

The 2012 USEPA Regional Screening Levels (RSLs) replace Preliminary Remediation Goals (PRGs) previously published by individual USEPA regions (e.g., USEPA, 2012). The USEPA RSLs have been incorporated into HDOH Environmental Action Levels for screening of potential direct-exposure hazards (HDOH, 2016).

The above list of references is not intended to be comprehensive. Additional HHRA guidance should be referred to as needed.