

Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater

Volume 1: User's Guide

Hawai'i Edition

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Summer 2008

(updated March 2009)

[Note: The Tier 1 EALs were updated in October 2008 to incorporate updates to the USEPA Region Screening Levels (USEPA 2008). Refer to Appendix 10 and the EAL Surfer for a summary of updates.]

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DISCLAIMER

This document, *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater* (Summer 2008), is a technical report prepared by staff of the Hawai'i Department of Health (HDOH), Environmental Management Division. The document updates and replaces the document *Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater* (Interim Final, May 2005 and interim updates).

The document provides guidance for identification and evaluation of environmental hazards associated with contaminated soil and groundwater. The Environmental Action Levels (EALs) presented in this document and the accompanying text are specifically *not* intended to serve as: 1) a stand-alone decision making tool, 2) guidance for the preparation of baseline environmental risk assessments, 3) a rule to determine if a waste is hazardous under the state or federal regulations, or 4) a rule to determine when the release of hazardous substances must be reported to the HDOH.

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ACKNOWLEDGEMENTS

This guidance represents the tenth edition of the original *Risk-Based Corrective Action* document published by the Hawai'i Department of Health in 1995. Other editions of this document were prepared by the same author for use as a consultant with Dames and Moore in the mid 1990s and with the California Environmental Protection Agency in from 1999 to 2005. The author is deeply indebted to the countless consultants, regulators and private individuals who provided their expertise on thousands of individual projects during this time period and continue to do so today. The guidance is an attempt to present their collective expertise in a manner that improves the efficiency and effectiveness of the work we undertake for the mutual benefit of all parties involved.

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Supplemental Models

(available for download from HDOH HEER office website)

- EAL SURFER (EXCEL)
- TIER 2 SOIL DIRECT EXPOSURE MODEL (EXCEL)
- TIER 2 GROUNDWATER VAPOR INTRUSION MODEL (EXCEL)
- VAPOR UNIT CONVERSION (EXCEL)
- BATCH TEST SOIL LEACHING MODEL (EXCEL)

Executive Summary

This document presents guidance for the expedited identification of environmental hazards associated with contaminated soil and groundwater and the preparation of *Environmental Hazard Evaluation* (EHE) reports. The document updates and replaces the document *Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater* (Interim Final, May 2005 and interim updates). A similar but less Hawai'i-specific guidance document published by the Guam Environmental Protection Agency (GEPA 2008) should be referred to for other areas of the Pacific Basin, with the concurrence of the local, overseeing regulatory agency. [The Tier 1 EALs were updated in October 2008 to incorporate updates to the USEPA Region Screening Levels (USEPA 2008). Refer to Appendix 10 and the EAL Surfer for details.]

An *Environmental Hazard Evaluation* should be carried out at all sites where contaminated soil or groundwater is identified. A brief but properly prepared EHE will in most cases replace what is traditionally known as an environmental "risk assessment." An important part of the EHE is the use of pre-approved, *Environmental Action Levels* (EALs) included in the lookup tables and *EAL Surfer* included in this guidance document (referred to as *Environmental Screening Levels* or *ESLs* in the Guam EPA guidance). The EALs are used to rapidly screen soil, soil gas and groundwater data collected for a site and identify potential environmental hazards. Under most circumstances, and within the limitations described, the presence of a chemical in soil, soil gas or groundwater at concentrations below the corresponding Tier 1 EAL can be assumed to not pose a significant threat to human health and the environment. This allows sites or portions of sites with minimal or no contamination to be quickly cleared for potential environmental concerns, a task which could easily take months or even years using a traditional, environmental risk assessment approach.

The EALs incorporate an enormous amount of technical expertise across fields as diverse as toxicology, geology, chemistry, physics, ecology, engineering and even economics. Much like driving a car, however, it is not necessarily to understand the technical intricacies of the EALs in order to use them. As potential environmental hazards are identified, additional expertise can be brought in as deemed necessary and cost-beneficial for remediation of the contamination.

Exceeding the Tier 1 EAL for a specific chemical does not necessarily indicate that the contamination poses significant environmental concerns, only that additional evaluation is warranted. A detailed review of specific hazards can be carried out if time- and cost-beneficial, or contamination that exceeds the EALs

can simply be remediated. This can even include the preparation of site-specific, human health or ecological risk assessments, although this level of effort will rarely be required for typical sites.

An EHE serves as the link between site investigation activities and the selection of final response actions. As potential environmental hazards are identified, the site investigation can be modified to ensure that adequate types and amounts of data are collected to understand the extent and nature of potential hazards. Once the site investigation and EHE are completed, *Environmental Hazard Maps* can be prepared to summarize the findings of the investigations and serve as a tool to help guide and design subsequent remedial efforts. The type of remedial actions required at the site will vary, depending on the nature of the environmental hazards identified (e.g., soil removal or capping to address direct exposure or leaching hazards versus soil vapor extraction to address vapor intrusion hazards).

The following information should be included in an EHE (or included in a report that contains the EHE):

- 1. Site History:** Brief summary of the site history and operations that lead to the release of hazardous chemicals;
- 2. Past Investigations and Remedial Actions:** Overview of past investigations and remedial actions;
- 3. Extent and Magnitude of Contamination:** Summary of the extent and magnitude of contamination in soil, soil gas and/or groundwater above Tier 1 EALs, clearly depicted on to-scale maps of the site;
- 4. Identification of Potential Environmental Hazards:** Identification of potential environmental hazards by comparison of site soil, soil gas and/or groundwater data to Tier 1 EALs as well as action levels specific hazards (latter especially important at sites where full cleanup to the Tier 1 EALs will not take place or alternative action levels will be considered);
- 5. Detailed Evaluation of Specific Environmental Hazards (optional):** Detailed evaluation of specific environmental hazards using approaches described in this document or alternative approaches approved by HDOH;
- 6. Conclusions and Recommendations:** Provides a summary of EHE findings and recommendations for followup actions.

The level of detail needed in the EHE will vary depending on the nature of the contamination and anticipated cleanup actions. A basic EHE should be used to screen for potential environmental hazards, identify data gaps and complete the

site investigation. The completed EHE should conclude with recommendations for followup actions, such as no further action, collection of additional data to better evaluate a specific environmental hazard or evaluation of remedial alternatives. At sites where full cleanup is not possible, an “as-built” EHE should be used to document the extent and magnitude of remaining contamination as well as potential environmental hazards posed by the contamination in the absence of institutional or engineered controls. This “as built” EHE serves as the basis for an *Environmental Hazard Management Plan* that describes ongoing measures to be taken to ensure that the contamination is properly managed in the future.

The Tier 1 EALs presented in the lookup tables are NOT regulatory "cleanup standards". Site-specific action levels and cleanup levels are, however, subject to the approval of published by the Hawai‘i Department of Health. EALs presented for chemicals that are known to be highly biodegradable in the environment may be excessively conservative for use as final cleanup levels (e.g., many petroleum-related compounds). Stand alone use of the Tier 1 EALs may be inadequate in some cases. Examples include sites with a high public profile that cannot be fully cleaned up and require a detailed discussion of potential risks to human health. Other examples include sites where physical conditions differ drastically from those assumed in development of the EALs (e.g., mine sites, landfills, etc., with excessively high or low pH) and sites where impacts pose heightened threats to sensitive ecological habitats. Use of the EALs as stand alone screening criteria or final cleanup levels should be evaluated in terms of overall site conditions and potential environmental hazards, the cost/benefit of developing site-specific cleanup levels as well as the pros and cons of full site cleanup versus long-term management.

The *Environmental Hazard Evaluation* approach described in this guidance is applicable to any site where contaminated soil and groundwater are identified, including sites that fall under the purview of the Comprehensive Environmental Restoration and Reclamation Act (CERCLA). The guidance will be of particular benefit to small-business owners and property owners with limited financial resources, for whom the preparation of traditional, Superfund-type risk assessments is generally not feasible or even necessary. The guidance is particularly useful as a rapid and cost-effective tool for the evaluation of brownfield or potential brownfield properties. This guidance will be updated as needed, in order to incorporate changes in the referenced sources as well as lessons gained from site investigation and response actions. Comments and suggestions are welcome at any time and should be submitted to the contacts noted at the beginning of this document.

1

Introduction

1.1 Environmental Hazard Evaluation

Environmental Hazard Evaluation is the link between the discovery of contaminated soil or groundwater during the *site investigation* and *response actions* taken to address this contamination (Figure 1-1). During this step of the overall environmental response process, the presence or absence of potential environmental hazards associated with contaminated soil and groundwater is determined. This is carried out initially by comparison of site data to pre-approved, Environmental Action levels (EALs) presented in Tables A through F at the end of this volume. If potential concerns are confirmed, then the specific hazards posed by the contamination are identified, the need for additional data to complete the site investigation is determined and the preparation of appropriate remedial actions is recommended.

Once the site has been adequately characterized, the most appropriate remedial action is determined. For sites where the extent of contamination is minimal or time is of the essence, the most cost-beneficial response may be the immediate removal of the contaminated media. In other cases, the potential cost of remediation or difficulty in accessing the contamination could preclude a complete cleanup. An advanced evaluation of specific environmental hazards is usually warranted at such sites. This may involve the development of site-specific cleanup levels and remedial actions to address the most pressing hazards (e.g., discharges of free product into storm sewers or vapor intrusion into overlying buildings). The extent and magnitude of the remaining contamination and the specific environmental hazards posed by the contamination is then documented in final site investigation and environmental hazard evaluation report. This is then used to prepare an *Environmental Hazard Management Plan* that presents guidelines for long-term management of the contamination and associated institutional and engineered controls.

Environmental Hazard Evaluations are therefore an integral part of site investigations and remedial actions. Site investigations and remedial actions carried out in the absence of a basic understanding of the environmental hazards posed by contaminated soil or groundwater run the risk of being incomplete. This can result in later, unanticipated requirements for additional actions and unnecessary delays and costs needed to bring the property back into productive use. The guidance presented in this document is intended to help avoid such surprises and make the investigation, evaluation and remedial action process as effective and efficient as possible.

1.2 Targeted Environmental Hazards

A basic understanding of environmental hazards associated with contaminated soil and groundwater is critical in the overall environmental response process (see Figure 1-1). Common environmental hazards that should be initially screened for at all contaminated sites include:

Soil:

- Direct-exposure threats to human health;
- Intrusion of subsurface vapors into buildings;
- Leaching and subsequent threats to groundwater resources;
- Threats to terrestrial habitats;
- Gross contamination and general resource degradation concerns;

Groundwater:

- Threats to drinking water resources;
- Threats to aquatic habitats;
- Intrusion of subsurface vapors into buildings;
- Gross contamination and general resource degradation concerns.

For the purpose of this document, "soil" refers to any unlithified material in the vadose zone that is situated above the capillary fringe of the shallowest saturated unit. Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2). Tier 1 Environmental Action Levels (EALs) for soil presented in this guidance are *not* directly applicable to soil that is situated within the capillary fringe zone or below the water table (refer to following section and Chapter 2).

A brief description of each hazard is provided in Figure 1-2. Detailed discussions of each hazard are provided in Chapters 3 and 4 and in Appendix 1. Additional site-specific environmental hazards that may need to be reviewed on a site-specific basis include the uptake of contaminants in garden produce and the erosion and runoff of contaminated soil into nearby surface water bodies.

Note that several of the environmental hazards listed above are not necessarily “risk-based,” at least in the traditional regulatory use of this term. 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 (and unfortunately common) for traditional, human health risk assessments to conclude that soil is “nontoxic,” even though the soil would ignite if a match was dropped on it. Nevertheless, the fact that the soil is flammable is clearly important to identify and discuss 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 into groundwater is also important to consider, even though this is often neglected in traditional risk assessments. Discharges of contaminated groundwater or free product into surface water bodies, either naturally or via seepage into storm sewers or via discharge during construction-related dewatering activities, can likewise pose significant environmental hazards to aquatic habitats.

The environmental hazard that drives the potential need for remedial action at a contaminated site depends on the toxicity and mobility of the targeted contaminants (refer to Appendix 1). Soil contaminated with chemicals that are highly toxic to humans and relatively immobile (e.g., arsenic, lead, PCBs, etc.) will generally be flagged as posing potential direct exposure hazards. Soil contaminated with volatile chemicals that are potential carcinogens (e.g., benzene, PCE, TPH gasoline, methane, etc.) are typically identified as posing potential vapor intrusion hazards. Soil contaminated with petroleum, solvents or highly mobile pesticides (e.g., TPH gasoline or diesel, BTEX, PCE, atrazine, etc.) will often be identified as posing potential leaching hazards. Soil contaminated with pesticides or metals that are relatively non-toxic to humans (e.g., barium, copper, nickel, etc.) can pose significant toxicity hazards to terrestrial flora and fauna.

Drinking water toxicity hazards are almost always identified for aquifers contaminated with hazardous chemicals. As is the case for soil, vapor intrusion hazards will often be identified for groundwater contaminated with carcinogenic, volatile chemicals. A number of chemicals pose potential aquatic toxicity hazards at relatively low concentrations, if the groundwater were to discharge into a sensitive aquatic habitat. Free product on groundwater poses gross contamination hazards that could lead to sheens or odor in surface water if allowed to migrate offsite (as well as vapor hazards). Gross contamination hazards could also be identified for drinking water contaminated with chemicals that have a low taste and odor threshold (e.g., TPH, ethylbenzene, toluene, xylenes, MTBE).

1.3 Tier 1 Environmental Action levels

Tier 1 *Environmental Action levels* (Tier 1 EALs) are concentrations of contaminants in soil, soil gas and groundwater above which the contaminants could pose a potential adverse threat to human health and the environment. Figure 1-3 summarizes the use of the Tier 1 EALs. 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 specific, tentatively identified hazards. The action levels, or approved alternatives, can be used to delineate specific areas of the site that require remedial actions. These actions can vary, depending on the hazard present and site conditions. An overview of the development of the Tier 1 EALs is provided in Chapter 2. A detailed discussion of the compilation and development of the EALs is provided in Appendix 1.

1.3.1 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 Hawai'i DOH web page (refer to contact information at beginning of guidance). Use of the EAL Surfer in Environmental Hazard Evaluation reports is highly recommended. Guidance on use of the Surfer and example printouts are provided in Chapter 3.

1.3.2 Use of EALs in Site Investigations

One of the most basic uses of the EALs is to identify potential contaminant of concern (COPCs) and guide completion of the site investigation. The initial list of COPCs established during a review of past site operations can be quickly narrowed down by direct comparison of soil and groundwater data to the Tier 1 EALs. Further consideration of contaminants that do not exceed Tier 1 EALs is not necessary. This assumes of course that existing data are representative of overall site conditions.

The lateral and vertical extent of contamination should be determined for COPCs that exceed the Tier 1 EALs (or approved, alternative action levels). Delineation of the extent of contamination to laboratory reporting or detection limits is often impracticable and, from a hazard evaluation standpoint, unnecessary. The

investigation can be considered complete once the extent of contamination in excess of Tier 1 EALs (or approved alternatives) is accomplished. The use of field screening methods, mobile labs and quick turnarounds in laboratory analyses will help expedite the completion of site investigation activities.

The identification of potential environmental hazards should begin as soon as the first data are received. This will help identify the need for alternative types of data that will be required for more detailed evaluations of specific hazards and completion of the site investigation. For example, if arsenic is reported in soil at concentrations above 20 mg/kg then laboratory bioaccessibility tests should be run on the same sample (refer to Chapter 4). If the reported concentration of volatile contaminants exceed action levels for vapor intrusion concerns then soil gas data should be collected. Incorporating these decisions rules in the sampling and analysis plan will help expedite completion of the site investigation as well identify potentially significant environmental hazards at the site that could require immediate action.

1.3.3 Use of EALs in Environmental Hazard Evaluations

The most important use of the Tier 1 EALs is the rapid identification of potential environmental hazards associated with contaminated soil and groundwater (refer to Section 3.1). With the exception of gross contamination, most of the environmental hazards noted earlier are not obvious in the field. An initial comparison of site data to the Tier 1 EALs provided in Tables A through F 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 EAL. The specific, potential environmental hazard(s) associated with the contaminant can then be identified. This process is described in more detail in Chapter 3. As discussed above, use of the EAL Surfer will significantly expedite this process.

Potential environmental hazards identified in a Tier 1, action level Environmental Hazard Evaluation can be evaluated on a more site-specific basis as needed (refer to Chapters 3 and 4). The information gained can be used to better define the need for additional site investigation as well as to help develop appropriate remedial options. The level of effort required for advanced evaluations can vary greatly. For example, only a minimal level of effort may needed to rule out potential hazards to terrestrial ecological habitats at a highly developed commercial or industrial site that does not contain significant natural habitat. Vapor intrusion is typically a potential hazard at VOC contaminated sites where occupied structures are present (or proposed). The collection of soil gas data at

these sites can be highly useful and in some cases required. A detailed review of groundwater data can replace soil action levels for leaching hazards at sites that have remained uncapped for a sufficiently long period of time for worst-case groundwater impacts to take place.

1.3.4 Use of EALs in Remedial Actions

In cases where contamination is limited, easily accessible and time is of the essence, it can be more cost-effective to aggressively remediate the impacted soil or groundwater to the Tier 1 EALs. The Tier 1 EALs are not strict cleanup standards, however, and should not be used as such. In cases where cleanup costs could be significant or complete cleanup is not practicable, the choice is not so clear and a more advanced evaluation of specific environmental hazards is usually warranted (refer to Chapters 3 and 4). Use of the detailed EALs presented in Appendix 1 of this guidance, and in particular use of the accompanying *EAL Surfer*, makes the identification of specific, potential environmental hazards relatively quick and easy. The information gained can then be used to evaluate specific environmental hazards in more detail and develop more efficient remedial actions.

Long-term management will be required for sites where contaminated soil and groundwater 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 identify 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). An overview of EHMPs is presented in Chapter 5.

1.4 Decision Unit and Multi-Increment Investigation Strategies

The use of *multi-increment sampling* and *decision unit* (MI/DU) site investigation strategies is strongly encouraged (Ramsey and Hewitt 2005). A brief introduction to these approaches is provided the Hawai'i Department of Health (HDOH) technical memorandum *Pesticides in former agricultural lands and related areas* (HDOH 2007a). A copy of this guidance is provided in Appendix 8. Additional guidance is provided in the updated edition the HDOH Hazard Evaluation and

Emergency Response (HEER) office's *Technical Guidance Manual* (HDOH 2008a). An overview of the MI/DU investigation approach is provided below.

1.4.1 Decision Units

A decision unit is an area over which a decision is to be made regarding the need to address contamination within that area. (Strictly speaking, a decision unit is really a volume of soil rather than an area, since the thickness of the decision unit is often a key factor.) A decision unit can be an identified spill area or "hot spot," a residential yard, a playground or schoolyard, a garden, a commercial/industrial property or other specific area of interest.

The location, size, and shape of a decision unit depend on the nature of the decision that will be made using the data to be collected. For example, if a site is being sampled to decide whether contaminants pose potential direct exposure hazards, then the size of the decision unit is based on the size of the area over which average exposure is assumed to take place (i.e., a 5,000 ft² house lot). The consideration of individual spill areas as separate decision units is generally necessary to assess leaching, vapor intrusion and gross contamination hazards posed by highly mobile and volatile chemicals. Examples include releases from pipelines or storage tanks, as well as heavily contaminated portions of pesticide mixing areas.

Discrete samples, or more preferably multi-increment samples collected over small areas, can be useful for delineation of spill area boundaries. The spill areas themselves should be sampled using multi-increment samples when feasible, however. Non-volatile contaminants in spill areas can be readily sampled using multi-increment sampling methods (refer to following section). Volatile contaminants can also be investigated with multi-increment sampling in these areas, although details are still to be worked out on appropriate field methods for multi-increment sampling to minimize VOC loss.

When using a decision unit strategy, the entire area of a decision unit is acted upon as a single entity based on the data collected from that unit, regardless of internal variation. If the data suggest that remediation is required, then this applies to the entire decision unit. This makes it important during the selection of decision units to isolate areas of obvious, heavy contamination in order to reduce the volume of soil or groundwater that must be treated. The isolation of heavily contaminated areas can be based on previous sampling data or other relevant indicators such as variations in soil type across the site, the presence of visible

soil stains or stressed vegetation, knowledge of past use of chemicals at the site, site topography, etc.

Alternative approaches for the use of decision unit strategies at very large sites (e.g., >50 acres) are briefly discussed in the May 2007 HDOH guidance for pesticide-contaminated sites provided in Appendix 8 (HDOH 2007a). In cases where large areas must be assessed, the cost of sampling when setting the decision unit to the size of a 5,000-square-foot residential house lot may be very high. To reduce sampling costs, initial screening of the area on the scale of large, neighborhood-scale decision units is recommended. More detailed investigation can then be carried out on randomly selected decision units the size of hypothetical residential lots. This approach can expedite the investigation and clearance of large tracts of land while also providing a relatively high degree of confidence in the data collected.

1.4.2 Multi-Increment Samples

Multi-increment samples should be collected from selected decision units whenever practicable. This sampling approach reduces the variability and improves the reliability of decision unit data in comparison to conventional, discrete sampling strategies. Thirty to fifty small *increments* of soil (typically 10 to 50 grams per increment) are collected from each specific decision unit of interest (see previous section). The increments are collected in a stratified-random manner (e.g., by collecting increments while walking up and down adjacent rows) and physically combined into one sample. The combined sample is analyzed to obtain a representative contaminant concentration for the entire decision unit. Multi-increment sampling data typically have low variability and high reproducibility, which results in a high level of confidence for decision-making. Multiple multi-increment samples collected from the same decision unit are referred to as *replicates*. Data for replicate samples can be statistically analyzed to help evaluate the precision of the field sampling methodology. HDOH recommends that three replicate samples, referred to as *triplicates*, be collected in 10% of the decision units to be investigated (minimum one set of triplicate samples per site).

Multi-increment sample mass is based on particle size and generally ranges from 500 to 2,000 grams. The laboratory dries the sample, and sieves it to <2mm particle size (this may also be done in the field). To obtain a representative subsample, the field sample must be processed so that the entire “population” of soil particles is accessible for collection. Sub-sampling can be accomplished with a sectoral splitter or by collecting a multi-increment sample using the same

approach as used to collect the field sample but with smaller tools and increment masses. A minimum subsample mass of ten grams is recommended in order to reduce lab fundamental error due to the range of particle sizes being tested. Note that this is greater than typically called for in some USEPA laboratory methods, especially for metals. Handling and analysis of a larger subsample mass should be discussed ahead of time with the laboratory.

Multi-increment samples can be collected for both nonvolatile and volatile contaminant analyses. When collecting samples for volatile contaminants, increments must be placed into an extraction solution in the field (e.g. methanol) in order to prevent VOC loss. However, since issues related to field extraction solutions, methanol transportation in the field, appropriate sample containers, elevated laboratory method reporting limits, etc., are still unresolved, this approach is not yet widely used. In the meantime, consultants who would like to use the approach should provide sampling and analysis work plans to HDOH for review and ensure close coordination with the receiving laboratory.

1.5 Guidance Organization

Volume 1 of this guidance document is kept intentionally brief and as non-technical as possible. The scope and use of the Tier 1 EALs is summarized in Chapter 2. Chapter 3 discusses the preparation of basic *Environmental Hazard Evaluations*. Chapter 4 presents more advanced approaches for the evaluation of specific environmental hazards. The final chapter provides guidance for the long-term management of contaminated sites that cannot be easily remediated, with a focus on petroleum-related contamination. Technical details regarding the compilation and development of the Tier 1 EALs are discussed in a series of appendices presented in Volume 2. The EAL Surfer and advanced models that accompany this guidance document are available for download from the Hawai'i DOH HEER office website (see contact information at front of document).

1.6 Limitations

The Tier 1 EALs presented in the lookup tables are NOT required, regulatory "cleanup standards". Use of the EALs as actual cleanup levels should be evaluated in view of the overall site investigation results and the cost/benefit of performing a more detailed environmental risk assessment. The EALs are intended to be conservative for use at the vast majority of impacted sites in developed areas. As discussed in Chapter 4, however, stand-alone use of the

EHE approach may not be appropriate for final assessment of all sites. Examples include:

- High profile sites that cannot be fully cleaned up and warrant a detailed, traditional human health or ecological risk assessment;
- Sites where more than three known or suspected carcinogens or more than five chemicals with similar noncarcinogenic health effects have been identified (generally not required at petroleum-contaminated sites, see section 2.4 for details);
- Sites with high rainfall (e.g., >250cm (100 inches) per year) and infiltration (e.g., >720mm (28 inches) per year) that overlie highly vulnerable and valuable groundwater resources (refer to Appendix 1, Table E-2);
- Sites where inorganic chemicals (e.g., metals) are potentially mobile in leachate due to soil or groundwater conditions different than those assumed in development of the lookup tables (e.g., low pH conditions at mine or landfill sites); and
- Sites affected by tides, rivers, streams, heavy rainfall, etc. where there is a potential for erosion of soil and concentration of contaminants in aquatic habitats through transport and deposition of contaminated soil particles.

The need for detailed human health or ecological risk assessments in these cases should be discussed with HDOH on a site-by-site basis.

Soil EALs do not consider potential water- or wind-related erosion and deposition of contaminated particles in a sensitive ecological habitat. This may especially be of concern for contaminants that are known to be bioaccumulative in aquatic organisms (e.g., mercury, PCBs and organochlorine pesticides) or heavy metals that are only moderately toxic to humans but highly toxic to aquatic and terrestrial biota (e.g., copper). At sites that pose an elevated threat to sensitive aquatic habitats, measures should be taken to mitigate potential erosion and runoff concerns.

Evaluation of landfills and sites impacted by mine wastes may in particular require a more detailed evaluation of contaminant fate and transport in soil and groundwater, as well as groundwater-surface water interactions, due to low pH issues. Action levels for leaching of metals in soil are not considered reliable and are not included in the Tier 1 EALs. Lab-based methods to evaluate this potential hazard are discussed in Chapter 4.

It is conceivable that soil, groundwater and soil gas action levels developed to address the emission of chlorinated volatile organic compounds to indoor air may not be adequately conservative in some cases. This is most likely to occur in enclosed buildings sites with poor ventilation designs or buildings with flooded basements. Additional guidance on the site-specific evaluation of vapor intrusion hazards is provided in Chapter 4.

The groundwater action levels presented in the lookup tables do not directly address the impact of long-term discharges of contaminated groundwater on sediment quality. The accumulation of potentially toxic metals in sediment over time could require a more detailed evaluation at some sites. The buildup of highly-sorptive (lipophilic), organic contaminants in sediment over time could likewise be a concern for petroleum-contaminated sites that are immediately adjacent to sensitive aquatic habitats (e.g., PAHs and other heavy petroleum compounds).

Direct-exposure action levels for construction and trench workers are incorporated into the Tier 1 soil EALs (see Appendix 1). The action levels consider ingestion and dermal contact with contaminated soil as well as the inhalation of vapors and dust, based on a construction worker exposure scenario. *The model used to evaluate inhalation of vapors does not fully consider soil that is being disturbed during excavation or exposed in trenches, however.* DOH is investigating the use of alternative models to make the action levels more applicable to these circumstances. **In the interim, exposure of workers to volatile contaminants in soil during construction or trench-related activities should be minimized and discussed in a properly prepared health and safety plan.**

2

Environmental Action levels

2.1 Introduction

Environmental Hazard Evaluations, as described in Chapter 3, are based on the use of *Environmental Action Levels* (EALs) to quickly screen soil, soil gas and groundwater data for potential environmental hazards. As reviewed below, individual action levels were developed to address each of the environmental hazards described in Section 1.2 for each contaminant listed in the lookup tables, as available and applicable (refer to Figures 1-1 and 1-2). The lowest action level represents the concentration of the contaminant in the respective media where the threat to human health or the environment is considered to be insignificant under any site condition. This is selected as that contaminants *Tier 1* EAL. Soil and groundwater Tier 1 EALs for approximately 150 common contaminants are summarized in Tables A through D. Action levels for soil gas, indoor air and surface water are presented in Table E and F. A detailed discussion of the development of the Tier 1 EALs is provided in Appendix 1.

The presence or absence of potential environmental hazards at a contaminated site is determined by the direct comparison of soil, groundwater and/or soil gas data to Tier 1 EALs for targeted contaminants of concern. Exceeding the Tier 1 EAL for a specific chemical does not necessarily indicate that the contamination poses a significant threat to human health or the environment, only that additional evaluation is warranted. The level of detail required for the additional evaluation will vary. In some cases it may be more cost-beneficial to simply remediate the site to the Tier 1 EALs than to conduct an advanced evaluation. A more detailed evaluation of specific environmental hazards is generally warranted in cases where significant cleanup costs may be incurred, where public sensitivity of the site is high or where long-term, *in-situ* management of the contamination is being considered.

More advanced approaches for evaluating specific hazards are presented in Chapter 4. The advanced approaches range from relatively simple methods that

do not require significant expertise in the specific hazard under investigation to very complex methods that will require a high level of technical expertise. It is anticipated, however, that only a very small number of sites will warrant highly technical and detailed environmental hazard evaluations.

The EAL Surfer (Excel-based electronic lookup tables) included with this guidance provides a relatively quick and easy method to screen site data and, as needed, identify specific, potential environmental hazards (refer to Chapter 3). Sample printouts from the Surfer can be included in the appendices of an EHE report for reference. **Use of the EAL Surfer to prepare *Environmental Hazard Evaluations* is strongly recommended.**

2.2 Organization of Lookup Tables

The Tier 1 EAL lookup tables are organized to reflect four default *conceptual site models* for contaminated sites in Hawai'i, based on groundwater utility and proximity to a surface water body (Figure 2.1):

	Drinking Water Resource Threatened	Drinking Water Resource NOT Threatened
≤150m to surface water	A-1	B-1
>150m to surface water	A-2	B-2

The first table presents soil and groundwater action levels for sites that directly overlie a current or potential source of drinking water (Table A). Two sets of action levels are provided, one for sites within 150m (500 feet) of a surface water body and one for sites located more than 150m (500 feet) from a surface water body. A second table presents a similar set of action levels for sites that do not directly overlie a current or potential source of drinking water (Table B).

The Tier 1 EALs for soil assume that contaminated soil is exposed at the ground surface or could be excavated and spread out at the ground surface at some time in the future. The Tier 1 EALs further assume that there are no restrictions on current or future use of the property, including potential use as residential housing, schools, day care, health care, etc. This approach minimizes the need for restrictions on future site use and highlight soils that must be properly managed if

complete remediation to unrestricted future use is not feasible. Alternative soil action levels for sites that will be restricted to commercial/industrial use only area included in Appendix 1 and included in the EAL Surfer (refer to Chapter 3). Use of these action levels for final site closure should be discussed with HDOH on a case-by-case basis, however, and could require the implementation of formal engineered and institutional controls.

Additional discussion of the primary factors used to prepare the default, conceptual site models and Tier 1 EAL lookup tables is presented in the following sections. Compilation of the Tier 1 EALs is discussed in more detail in Appendix 1.

2.3 Use of Lookup Tables

The step-by-step use of the Tier 1 EAL lookup tables and preparation of an *Environmental Hazard Evaluation* is summarized below and in Figure 1-3. A detailed discussion of *Environmental Hazard Evaluation* reports is provided in Chapter 3.

Step 1: EAL Updates and Applicability

Check the HDOH web page listed at the beginning of this guidance to ensure that the most up-to-date version of this document is being used. Review the limitations discussed in Section 1 to determine if the EALs are applicable to the subject site.

Step 2: Identify All Chemicals of Potential Concern

An *Environmental Hazard Evaluation* (EHE) must be based on the results of a thorough site investigation, where all chemicals of potential concern have been identified. A summary of the site investigation results should be included in the EHE in order for it to be reviewed as a "stand alone" document. An outline of the information that should be included in an EHE is provided in Section 2.9.

Step 3: Select Lookup Table(s)

Determine the beneficial use of impacted or threatened groundwater beneath the site and the distance to the nearest surfaced water body from the downgradient edge of the release site (refer to Figure 2.1). In general, all groundwater inland of the Underground Injection Control (UIC) lines should initially be treated as a current or potential source of drinking water (see Section 2.3, Appendix 8). Reference can be made to the Water Resources Research *Center Aquifer Identification and Classification* reports, however, to evaluate the utility of the groundwater on a more site-specific basis. This information is then used to select

soil and groundwater action levels in Table A (potential source of drinking water) or Table B (not a potential source of drinking water).

Step 4: Select Soil and/or Groundwater EALs

Select appropriate soil EALs from the appropriate lookup table. EALs for groundwater are provided in the adjacent column of each table and are not dependent on land use or depth to impacted soil. Replace EALs with naturally occurring, background concentrations of chemicals of concern (e.g., assumed background arsenic = 20 mg/kg) or laboratory method reporting levels if higher (see Section 2.6). For areas of high rainfall (>200cm/year), additional soil action levels for elevated leaching concerns should also be considered (refer to Table 2-1 in Chapter 2).

Step 5: Determine Extent of Impacted Soil and/or Groundwater

Using the selected EALs, determine the extent of impacted soil or groundwater and areas of potential environmental hazard at the site and offsite, as required. (Soil data should be reported on a dry-weight basis. While this is not likely to affect final cleanup decisions, it is more in line with assumptions used to develop direct-exposure action levels for human health concerns. See also Appendix 1, Section 6.2.) If a groundwater plume originating from an inland release site is suspected to have migrated to within 150m of a surface water body, then additional downgradient investigation may be necessary, using more conservative action levels for this zone.

Step 6: Evaluate the Need for Additional Investigation or Corrective Actions: Submit EHE Report

A detailed discussion of EHE reports is provided in Chapter 3. Based on a comparison of available site data to the EALs, evaluate the need for additional action at the site (e.g. additional site investigation, remedial action, preparation of a more site-specific risk assessment, etc.). For sites where sample data are limited, it will be most appropriate to compare the maximum-detected concentrations of chemicals of concern to the EALs to initially evaluate potential environmental concerns.

The collection of multi-increment sample (MIS) data is recommended when possible (refer to Section 1.4). Statistical methods can be used to estimate representative contamination concentrations in individual decision units at sites where only discrete sample data are available. This is generally selected as the lesser of the maximum-detected concentration and the 95% upper confidence interval of the arithmetic mean of sample data. Additional guidance on the estimation of representative contamination concentrations from MIS and discrete

sample data is included in the 2008 edition of the HDOH/HEER office *Technical Guidance Manual*. Guidance on the statistical evaluation of environmental data is also provided in the California EPA documents *Preliminary Endangerment Assessment Guidance Manual* (CalEPA 1994b) and *Supplemental Guidance for Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities* (CalEPA 1996), among other sources.

This evaluation should be summarized in the EHE report and workplans for additional actions prepared as needed (see Section 2.9). Decisions for or against additional actions should be made in conjunction with guidance from HDOH. Adjustment of Tier 1 action levels in a more advanced, environmental hazard evaluation is discussed in Chapter 4.

2.4 Default Conceptual Site Models

2.4.1 Land Use

The Tier 1 EALs for soil listed in Tables A and B were developed to allow unrestricted current and future use of a property. This includes consideration of direct exposure action levels suitable for use of the site as residences, hospitals, day-care centers, and other sensitive purposes (refer to CalEPA 2002). Action levels for unrestricted land use incorporate conservative assumptions with respect to long-term, continuous exposure of children and adults to impacted soils in a residential setting (see Appendices 1 and 2). As discussed in Chapter 3, alternative (and potentially less stringent) soil action levels for site that will be restricted to commercial/industrial land use only can be considered on a case-by-case basis.

2.4.2 Exposed versus Isolated Contaminated Soil

The Tier 1 EALs are based on an assumption that contaminated soil is currently exposed at the ground surface or could be excavated and exposed at the surface in the future. This assumption eliminates the need to consider long-term management of soil that is not currently exposed. As discussed in Chapter 4, the potential for deep or otherwise isolated contaminated soil to be exposed at the ground surface can be reviewed on a site-specific basis as needed.

2.4.3 Groundwater Utility

Groundwater utility is determined based on the location of the site with respect to the Underground Injection Control (UIC) Line and the state *Aquifer Identification and Classification* technical reports prepared by the University of Hawai'i (refer to Figure 2.1). This procedure is summarized in a policy update dated September 19, 1995 (see Appendix 8). Groundwater situated mauka (inland) of the UIC line is considered a potential source of drinking water, provided it is present in a suitably productive geologic formation. *Aquifer Identification and Classification* reports for individual islands can be referred to for more detailed information of groundwater aquifers located in these areas. Groundwater situated makai (oceanward) of the UIC line is generally considered to not be a potential source of drinking water, due to high salinity, low permeability and production and/or historic contamination.

In general, soil and groundwater action levels are more stringent for sites that threaten a potential source of drinking water (see Tables A and B). This is particularly true for chemicals that are highly mobile in the subsurface and easily leached from impacted soil. For chemicals that are especially toxic to aquatic life, however, Tier 1 action levels for sites that threaten drinking water resources may be driven by surface water/aquatic habitat protection concerns rather than by drinking water concerns. Many of the metals and pesticides listed in the lookup tables fall into this category (see Section 1.2). Refer to the detailed, F-series lookup tables in Appendix 1 or use the EAL Surfer for individual contaminants.

2.4.4 Threat to Surface Water Habitats

The conceptual site models used to develop the Tier 1 EALs assume that contaminated groundwater at all sites could at some time migrate offsite and discharge into a body of surface water (refer to Section 1.2). This could occur due to the natural, downgradient migration of groundwater or to human activities such as dewatering of construction sites. To address this concern, Tier 1 groundwater EALs both drinking water sources (Table A) and non-drinking water sources (Table B) include consideration of surface water goals for aquatic toxicity (refer to Chapter 2 of Appendix 1).

Promulgated water quality standards and correlative action levels for contaminants that lack promulgated standards are presented in Table D. The selection of action levels for contaminants that lack promulgated standards is discussed in Appendix 1. Tidally influenced portions of creeks, streams and

rivers and the bays they flow into are considered to be *estuarine* environments. Screening levels for estuarine environments are based on the more stringent of screening levels for marine (saltwater) versus freshwater environments but do not consider drinking water standards or screening levels. Chronic surface water standards (or equivalent) are incorporated into the groundwater screening levels to address potential aquatic habitat protection concerns.

In freshwater environments, screening levels (or promulgated standards) for most chemicals for drinking water concerns are generally much lower than corresponding standards for toxicity to aquatic organisms. For many pesticides and heavy metals, however, aquatic habitat goals are more stringent than drinking water toxicity goals and therefore drive the selection of final Tier 1 EALs (e.g., dieldrin, endrin and endosulfan). This is reflected in the final groundwater screening levels for these contaminants (refer also to Appendix 1 and the EAL Surfer).

Concentrations of contaminants in groundwater should meet chronic surface water goals at the point that the groundwater discharges into a sensitive aquatic habitat. Chronic surface water goals are therefore included in development of action levels for groundwater situated within 150m of a surface water body (Zones A-2 and B-2 in Figure 2.1; refer to Appendix 1). This is likely to be overly conservative for many petroleum-contaminated sites but is appropriate under a Tier 1 evaluation. If long-term monitoring of groundwater (e.g., two-plus years) adequately demonstrates that a plume is not likely to discharge into a surface water body above chronic goals even though it is within 150m of the body, then acute surface water goals can be used as final cleanup and closure levels.

Acute surface water goals are included in development of groundwater action levels for sites located more than 150m from a surface water body (Zones A-1 and B-1 in Figure 2.1; refer to Appendix 1). An argument could be made that plumes of petroleum-contaminated groundwater beyond this distance will never naturally migrate to a surface water body and that this concern does not need to be addressed. Plumes of heavily contaminated groundwater in inland areas pose potential concerns for future construction or utility maintenance related activities, however. It is important that the presence of these plumes is identified ahead of time and actions take to ensure that contaminated groundwater is not inadvertently discharged to storm sewers without adequate testing and treatment. Documenting the nature and location of inland plumes that do not otherwise pose a threat to human health and the environment is especially important for contaminants that do not readily biodegrade, such as chlorinated solvents and

MTBE. Additional characterization and monitoring of groundwater impacted with these contaminants may be needed if it is suspected that the plumes could move to within 150m of a surface water body at levels above chronic surface water goals.

The groundwater action levels do not consider dilution of groundwater upon discharge to a body of surface water. Benthic flora and fauna communities situated below or at the groundwater/surface water interface are assumed to be exposed to the full concentration of chemicals in impacted groundwater. Use of a generic "dilution factor" to adjust the surface water protection action levels with respect to dilution of groundwater upon discharge to surface water was therefore not considered. Consideration of dilution/attenuation factor and alternative groundwater action levels for the protection of surface water quality may, however, be appropriate on a limited basis in highly developed, industrial waterfront areas.

The soil and groundwater action levels presented in the lookup tables do not directly address the protection of sediment quality. Site-specific concerns could include the accumulation and magnification of concentrations of highly sorptive chemicals in sediment over time due to long-term discharges of impacted groundwater. This may be especially true for groundwater impacted with highly sorptive (lipophilic) chemicals, including heavy petroleum products.

Potential erosion and runoff of surface soils from impacted sites may also need to be considered, particularly at sites impacted with metals and pesticides that are situated near a sensitive body of surface water. The need for a more detailed, ecological risk assessment of impacts to sediment should be evaluated on a site-by-site basis and discussed with the Department of Health.

2.5 Compilation of Environmental Action levels

2.5.1 Tier 1 EALs

A detailed discussion of the compilation of all action levels is provided in Appendix 1. Approximately 150 chemicals are listed in the lookup tables. For each chemical, an action level was compiled to address each of the environmental hazards noted above, as applicable and available. The lowest of the individual action levels for each hazard was selected for inclusion in the summary lookup tables. This ensures that the Tier 1 EALs are protective of all potential environmental concerns and provides a tool for rapid screening of site data.

Where EALs are exceeded, the detailed tables provided in Appendix 1 can be used to identify the specific environmental concerns that may be present at the site.

A summary of the sources used to compile action levels for individual environmental hazards is provided in Figure 2-2. A detailed discussion of each source and associated models is provided in Appendix 1. In most cases, the action levels were drawn from published references (e.g., published drinking water and surface water standards). In other cases, published models were used to develop action levels for the subject environmental hazard (e.g., vapor intrusion action levels).

An example of the selection of summary, Tier 1 EALs for benzene is presented in Figure 2-3 unrestricted (“residential”) land use, drinking water resource threatened, site $\leq 150\text{m}$ from a surface water body). 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 presented in Table A of the summary lookup tables. For groundwater, the action level for drinking water toxicity concerns drives environmental hazards and is selected as the Tier 1 EAL presented in Table A (5 ug/L, the primary drinking water standard). A more detailed discussion of this example is provided in Appendix 1.

The driving environmental hazard for a specific chemical depends largely on the toxicity and mobility of the chemical. This can be seen by a review of the detailed lookup tables in Appendix 1 or by using the EAL Surfer to browse through various chemicals under different site scenarios. Tier 1 EALs for highly mobile or highly toxic chemicals in soil are typically driven by leaching or vapor intrusion concerns (e.g., see selection process for benzene Tier 1 EAL in Figure 2-3). Tier 1 EALs for chemicals that are relatively immobile in soil but highly toxic to humans are typically driven by potential direct-exposure concerns (e.g., PCBs and lead). In contrast, Tier 1 EALs for heavy metals that are relatively non-toxic to humans are typically driven by ecological concerns or ceiling levels for general resource degradation (e.g., copper and total chromium). For chemicals that have particularly strong odors, pose explosive hazards, or could cause sheens on surface water the selection of Tier 1 EALs may be driven by gross contamination concerns (e.g., Total Petroleum Hydrocarbons (TPH) and phenols). The consideration of gross contamination becomes especially important in the selection of EALs for relatively immobile chemicals in deep or otherwise isolated soils (refer to Section 4.5).

Driving environmental hazards are similar for groundwater. Tier 1 EALs for contaminants that are highly toxic to humans tends to be based on drinking water toxicity concerns (e.g., PCE; assuming the groundwater is a potential source of drinking water). Action levels for taste and odor concerns drive the selection of Tier 1 EALs for several, less toxic chemicals in drinking water supplies (e.g., xylenes and ethylbenzene). Tier 1 EALs for contaminants that are highly toxic to aquatic organisms are often based on chronic surface water standards, even if the groundwater is used as a source of drinking water (e.g., DDT and dieldrin). Vapor intrusion into buildings drives the selection of Tier 1 EALs for carcinogenic, highly volatile contaminants for groundwater that is not used as a source of drinking water (e.g., PCE and vinyl chloride).

2.5.2 Areas of High Rainfall (>200cm/year)

Soil action levels presented in Tables A and B are based on an assumption that annual rainfall at the site is less than 200cm (approximately 80 inches). This was used to develop soil action levels for leaching concerns and protection of groundwater quality. For sites located in areas of significantly higher rainfall, more stringent soil action levels for leaching concerns are appropriate. This is especially important for sites contaminated with chlorinated solvents or other highly persistent and mobile compounds that are often identified as contaminants in groundwater resources.

Additional action levels for common contaminants in soil that are highly leachable are provided in Table 2-1. These action levels were taken from the 1996 HDOH RBCA document and adjusted to reflect updated groundwater action levels. For sites where the annual rainfall exceeds 200cm/year, these screening levels should be used in conjunction with soil screening levels in Tables A and B. Guidance for more site-specific evaluation of potential leaching hazards is provided in Chapter 4.

2.6 Contaminants of Potential Concern at Petroleum Release Sites

2.6.1 Recommended Target Indicator Compounds

Recommended, target analytes for petroleum contaminated soil and groundwater are provided in Figure 2-4. This table was originally published in the HDOH HDOH technical memorandum *Long-Term Management of Petroleum-Contaminated Soil and Groundwater* (HDOH 2007c). Information from the memorandum has been incorporated into this guidance document.

Petroleum is a complex mixture of hundreds of different compounds composed of hydrogen and carbon or "hydrocarbon" compounds (API 1994). The bulk of these compounds are evaluated collectively under the all-inclusive category of "total petroleum hydrocarbons (TPH)", typically measured in three ranges: gasoline, middle distillates, and residual fuels. Gasoline-range TPH is a petroleum mixture characterized by a predominance of branched alkanes and aromatic hydrocarbons with carbon ranges of C6 to C12 and lesser amounts of straight-chain alkanes, alkenes, and cycloalkanes of the same carbon range (see also NEIWPC 2003, included in Appendix 7). Total Petroleum Hydrocarbon associated with middle distillates (e.g., kerosene, diesel fuel, home heating fuel, jet fuel, etc.) is characterized by a wider variety of straight, branched, and cyclic alkanes, PAHs (especially naphthalenes and methyl naphthalenes), and heterocyclic compounds with carbon ranges of approximately C9 to C25. Residual fuels (e.g., Fuel Oil Nos. 4, 5, and 6, lubricating oils, mineral oil, used oils, and asphalts) are characterized by complex polar PAHs, naphthoaromatics, asphaltenes, and other high-molecular-weight saturated hydrocarbon compounds with carbon ranges that in general fall between C24 and C40.

Due to the complex nature of petroleum mixtures, petroleum contamination should be evaluated in terms of both Total Petroleum Hydrocarbon (TPH) and target "indicator chemicals" for the specific type of petroleum product released (e.g., benzene, toluene, ethylbenzene and xylenes [BTEX], methyl tertiary butyl ether [MTBE], polynuclear aromatic hydrocarbons [PAHs], etc.). Target indicator chemicals typically make up only a small fraction of the total petroleum present but are important players in the assessment of environmental hazards posed to human and the environment.

Seventeen priority pollutant PAHs are listed in the USEPA Regional Screening Level (RSL) guidance (USEPA 2008a):

- acenaphthene
- acenaphthylene
- anthracene
- benzo(a)anthracene
- benzo(b)fluoranthene
- benzo(g,h,i)perylene
- benzo(a)pyrene
- benzo(k)fluoranthene
- chrysene
- dibenzo(a,h)anthracene
- fluoranthene
- fluorene
- indeno(1,2,3)pyrene,
- methyl naphthalenes (1 & 2)
- naphthalene
- phenanthrene
- pyrene

Both 1- and 2- methylnaphthalenes are combined in the EALs due to a lack of separate toxicity factors and fate and transport constants for development of separate action levels. The suite of PAHs that should be tested for at a given site depends on the type of the petroleum product released (after MADEP 2002a). As indicated in the Figure 2-4, only naphthalene needs to be tested for at gasoline release sites. Both methylnaphthalenes and naphthalene should be tested for at sites with releases of middle distillates (diesel, jet fuel, etc.). The full suite of PAHs should be considered at sites with releases of heavier petroleum fuels and waste oil, unless site-specific information on the product released can be used to justify elimination of specific PAHs.

Volatile components of petroleum that are not specifically identified as target indicator compounds in Figure 2-4 but reported as separate compounds by the laboratory using Method 8260 or similar methods can in general be ignored (e.g., alkanes, alkenes, alkyl benzenes and other aromatics not specifically identified as target indicator compounds; refer to Section 2.11 and NEIWPC 2003). These compounds are included under the umbrella analysis for TPH in general and do not need to be evaluated (or even reported) separately. This is based on the assumption that the toxicity factors selected for TPH are adequately conservative for the mixture of compounds present in fuels beyond the target compounds noted in Figure 2-4 (refer to Appendix 1, Chapter 5).

Soil, groundwater and soil gas samples must always be tested for TPH (or equivalent) in addition to targeted, individual chemicals. Laboratory analysis for TPH as gasolines and middle distillates is generally carried out using gas chromatography, modified for "gasoline-range" organics ("Volatile Fuel Hydrocarbons") and "diesel-range" organics ("Extractable Fuel Hydrocarbons"), respectively (e.g., EPA Method 8015). Analysis for TPH as residual fuels up to the C40 carbon range can be carried out by gas chromatography, infrared absorption, or gravimetric methods. The latter methods are rarely used, however, due to their inability to discriminate the type of the petroleum present and interference with organic material in the soil. Analysis of soil gas for TPH is commonly reported as *Total Volatile Hydrocarbons* or *TVH*. Consult a laboratory with expertise in analysis of total hydrocarbon fractions in soil gas for additional information.

Environmental action levels for TPH are developed by assigning representative fate and transport properties and toxicity factors to surrogates for each TPH category and applying the same models and approaches as used for the target, indicator compounds (refer to Appendix 1). A more in-depth analysis of the specific

components of the TPH can be carried out in a site-specific environmental hazard assessment as needed.

From an environmental hazard standpoint, cleanup of releases of gasolines is usually driven by a combination of TPH and benzene, with fuel oxygenates such as MTBE playing an important role in some cases. The cleanup of middle distillate fuel releases is usually driven by TPH, rather than by VOCs or PAHs. Naphthalene and methylnaphthalenes are two potential exceptions, since they can be present in middle distillate fuels at relatively high concentrations and are moderately volatile and mobile that TPH in general. Naphthalene is under study as a contaminant of interest in research on vapor intrusion, although it is unlikely that naphthalene as a vapor intrusion hazard would be a driving environmental concern at petroleum release sites due to the relatively low naphthalene content of typical petroleum mixtures. At sites where naphthalene could pose a vapor intrusion hazard, the most significant environmental hazards present would be posed by the very high concentrations of TPH, rather than by the naphthalene.

Soil and groundwater contaminated with middle distillate fuels must also be tested for BTEX (refer to Figure 2-4). Although BTEX rarely drives cleanup for releases of middle distillate fuels, their presence or absence is a useful indicator of past gasoline releases at the site or the migration of gasoline-contaminated groundwater onto the property from offsite sources. Testing for naphthalene at gasoline release sites is also recommended (refer to Figure 2-4).

The chemical composition of gasolines and middle distillates can be presumed with reasonable confidence. In contrast, the chemical composition of soil and groundwater contaminated by residual fuels, used oils, coal tar, asphalt, and other heavy petroleum mixtures is less predictable. Engine combustion processes may add PAHs, VOCs, and metals to used motor oils. Releases from used oil storage tanks may contain other liquids disposed of in the tanks, such as cleaning solvents, PCB transformer oils, or pesticides, in addition to used oil. Due to this potential for additional contaminants, the list of analytes for residual fuels is quite large. The need to test for certain analytes can be ruled out on a site-by-site basis, however, if it can be documented with confidence that the product released was fresh and uncontaminated. For example, releases of unused lube oil, transformer oils, mineral oils, virgin hydraulic oils and similar products do not require testing for PAHs and other chemicals if it can be demonstrated that product released was never heated to high temperatures (potentially producing PAHs) and not likely to be contaminated with solvents or metals.

2.6.2 Ethanol

Ethanol should be tested for at release sites where it is a known or suspected fuel additive or where it was stored or transferred. Toxicity factors are not available for ethanol (refer to Appendix, Table H). Ethanol is not believed to be significantly toxic at concentrations likely to be found in contaminated soil or groundwater. It is also readily biodegradable under both aerobic and anaerobic conditions and not anticipated to persist in the environment for long periods of time. Tier 1 soil, groundwater and indoor air action levels presented in this guidance are therefore based on gross contamination hazards only (odors in soil, taste and odor in drinking water supplies, generation of explosive vapors, etc., refer to Appendix 1).

In addition to gross contamination hazards, ethanol's high rate of biodegradability may result in additional adverse impacts, including (after MADEP 2002a):

- Increased levels of gasoline constituents in groundwater, including the MTBE, benzene, toluene, ethylbenzene and xylenes due to cosolvency effects in the presence of high concentrations of ethanol; and
- Longer plumes of petroleum-contaminated groundwater and other dissolved gasoline hydrocarbons due to the high biochemical oxygen demand exerted by ethanol and the depletion of oxygen and nutrients available for the degradation of other constituents. This has implications for natural attenuation considerations as a long-term cleanup remedy.

2.7 Contaminants of Potential Concern for Former Agricultural Lands

Testing of soils is recommended for sites where long-term application of pesticides may have occurred before they are developed for unrestricted (e.g., residential) or commercial/industrial use. This is especially pertinent to large tracts of former agricultural land, golf courses and nurseries. This also includes military bases where housing complexes that may have been treated with organochlorine-based termiticides are being demolished and redeveloped with new homes (refer to discussion of technical chlordane in Section 4.2).

In the case of former agricultural lands, contamination is likely to be heaviest in former pesticide mixing and staging areas, seed dipping areas and storage areas, although heavy contamination could occur in association with bagasse piles,

settling ponds, former plantation camp areas, etc. Residual contamination in former fields is likely to be much lower, although significant arsenic contamination has been identified in some areas of former sugar cane fields in Hawai'i (HDOH 2006a).

Types of pesticides commonly used in agricultural lands in Hawai'i include:

Pesticide Group & Related Contaminants	Standard USEPA Laboratory Method
Organochlorine pesticides	8081A
Organophosphorus pesticides	8141A
Chlorinated herbicides	8151A
*Triazine herbicides	8141A/8270C
Pentachlorophenol	8151A/8270C
Carbamates	8321A
Fumigants	8260
Dioxins/furans	8280/8290
Heavy metals (primarily arsenic, lead & mercury)	various

*Includes: ametryn, atrazine and simazine

Additional guidance on the selection of target pesticides in former agricultural areas will be provided in Section 9 of the updated, HDOH/HEER office *Technical Guidance Manual* (HDOH 2008a). The above list is not intended to be comprehensive, nor is it intended to represent a required list of target analytes. Specific pesticides of concern should be based on a review of the historical use of the site with a focus on pesticides that may be persistent in soil above Tier 1 EALs. Soil and groundwater action levels for the majority of commonly used, persistent pesticides in are included in this document. To obtain action levels for pesticides not listed in the lookup tables, contact HDOH or follow the guidelines used to develop the Tier 1 EALs in Appendix 1.

Organochlorine pesticides are known to be very persistent in soils, as are arsenic and lead. Organophosphate pesticides, chlorinated herbicides, triazines, carbamates and pentachlorophenol are susceptible to biological and chemical breakdown over time and are more likely to be persistent above levels of potential concern in heavily contaminated, pesticide mixing areas than in fields. Testing of former field areas for the full suite of pesticides at a action level is generally recommended, however (excluding fumigants beyond one-year of last application). As discussed in Chapter 4, significant levels of arsenic (associated with the use of lead arsenate or arsenic trioxide) and dioxins/furans (associated with the use of pentachlorophenol, 2,4,5 TP, etc.) can remain in soil even though the parent pesticide has degraded below levels of concern. Fumigants are not

likely to persist in shallow soils more than one year after use due to a propensity to volatilize into the atmosphere and degrade or be carried downward in leachate. The collection of shallow soil gas data (e.g., 1.5m/five ft bgs) in addition to soil data is recommended if fumigant contamination is suspected (refer to Section 4.4). Areas of past fumigant storage, mixing and distribution points should be targeted. Testing of large field areas for fumigants more than a year after the last application is generally considered unnecessary.

2.8 Laboratory Reporting Limits and Ambient Background

In cases where an EAL for a specific chemical is less than the standard, method reporting limit for a commercial laboratory (as agreed upon by HDOH), it is generally acceptable to consider the method reporting limit in place of the action level. Potential examples include groundwater action levels that are in the parts-per-trillion range for some PAHs and pesticides (e.g., PCBs, DDT, benzo(a)pyrene, etc.). Most of the contaminants involved are highly sorptive and not significantly mobile in groundwater. Lower reporting limits could be required in rare cases where discharges of groundwater known to be contaminated with these chemicals poses a significant threat to an aquatic habitat.

In the case of both soil and groundwater, sample analyses that are below the method reporting limit for the subject chemical should be reported in summary tables as “ND” (“non-detect”) with the laboratory method reporting level noted in parentheses (e.g., “ND (<0.5 ug/L)”). An alternative is to simply note “ND” in the cell for the chemical and sample number and note the method reporting limit table at the bottom of the table for each chemical.

A summary of typical, background concentrations of metals in soils is currently being prepared by HDOH. Assumed, background concentrations of arsenic (up to 20+ mg/kg) and total chromium (up to 500+ mg/kg) are incorporated into the Tier 1 EALs. These background concentrations are primarily based on data for soils developed over basaltic bedrock, commonly used for fill material in developed areas.

This is particularly an issue for arsenic. Background concentrations of arsenic in soils typically range from 5 mg/kg to 20 mg/kg, with some soils containing in excess of 40 mg/kg (refer to Appendix 1). This is well above purely risk-based, direct-exposure action levels for arsenic in soil of 0.43 mg/kg for residential exposure and 1.9 mg/kg for commercial/industrial exposure (refer to Table I series in Appendix 1 or EAL Surfer). The direct exposure action level is based on

an assumption that 100% of the arsenic in the soil is bioavailable or potentially toxic. This is almost never the case for arsenic-contaminated soils in Hawai'i. Site-specific bioaccessibility tests are recommended when a total arsenic concentration of 20 mg/kg is exceeded (refer to Chapter 4). Based on bioaccessibility data reviewed by HDOH, pesticide-related arsenic present in soil below this concentration is likely to be strongly bound to soil particles and not significantly toxic.

Chromium III is not significantly harmful to humans and rarely causes toxicity concerns. Chromium VI, however, is highly toxic and an important contaminant of potential concern where it was used in industrial processes or otherwise created due to human activities (e.g., treatment of contaminated soil or groundwater, etc.). If reported levels of total chromium exceed 500 mg/kg *or if the release of chromium VI at the site is otherwise suspected* then soil samples should be tested for both chromium VI and chromium III and the data compared to action levels for these specific species of chromium. Note that background concentrations of total chromium in soils developed over caprock can be lower than 100 mg/kg.

2.9 Land-Use Restrictions Inherent in Tier 1 EALs

The Tier 1 EALs presented in Tables A and B are based on an assumed current or potential unrestricted ("residential") land use (refer to Section 2.4.1). This allows sites to be initially screened for unrestricted land use. Risk-based action levels for commercial/industrial land use scenario are included in Appendix 1. An option to screen data based on assumed commercial/industrial land use is also incorporated into the EAL Surfer (refer to Chapter 3).

Allowing the option to tie action levels or cleanup levels to site-specific land use and exposure conditions can save considerably in investigation and remediation costs. For example, the action level for polychlorinated biphenyls (PCBs) in surface soils is 1.1 mg/kg in residential areas but up to 7.4 mg/kg for commercial/industrial areas (based on a target cancer risk of 10^{-5} and noncancer hazard quotient of 1.0). Higher levels can potentially be safely left in place if proper institutional and engineered controls are implemented and an adequate Environmental Hazard Management Plan is prepared (refer to Chapter 5).

The use of cleanup levels less stringent than those appropriate for unrestricted land use may place significant restrictions on future use of the property. For example, if a site is remediated to meet EALs (or alternative criteria) intended for commercial/industrial land use then the site could not be used for residential

purposes in the future without additional evaluation. In some cases, this may require that a formal covenant to the deed be recorded to restrict future use of the property. Deed covenants are generally not necessary for petroleum-release sites unless significant vapor intrusion hazards are present (refer to Chapter 4). Residual petroleum contamination will naturally degrade once the source of the release and gross contamination are removed. Petroleum-contaminated soil or groundwater is also easily recognized at levels that pose potential direct exposure hazards in the field.

The use of alternative action levels for deep or otherwise isolated soils assumes that the impacted soil will remain isolated below the ground surface "for eternity" (refer to Section 4.5). For single-family residential areas, future disturbance of soil situated deeper than three meters is generally considered to be unlikely (CalEPA 1996). The use of alternative EALs for soil located below this depth is reasonable (see Section 4.2). For commercial/industrial sites, soils situated below a depth of one meter are assumed to be "isolated" and not likely to be exposed during unauthorized subsurface activities. For persistent contaminants, the placement of formal institutional controls on the property is recommended to clearly document the presence of isolated contamination and prevent inadvertent disturbance in the future (refer to Chapter 5).

During the redevelopment of properties for commercial/industrial or high-density residential use, excavation and removal of soils from depths up to five or greater is possible (e.g., for underground parking garages, elevator shafts, utilities, etc.). The need to impose enforceable institutional controls for proper management of deep or otherwise isolated, contaminated soils at commercial/industrial properties where action levels for isolated soils are applied should be discussed with HDOH on a site-by-site basis.

In general, land-use restrictions inherent in the selection of EALs from the Tier 1 lookup tables (or assumptions used in site-specific risk assessments) should be kept as minimal as possible. **When preparing EHEs for commercial/industrial sites, concentrations of chemicals in impacted soils left in place should always be compared to action levels for both unrestricted land use and commercial/industrial land use only.** If the soils in fact meet EALs for unrestricted land use after cleanup then this should be clearly stated in the site closure report. There is no need to compare confirmation data to action levels for commercial/industrial land use only. Recognizing this upfront will help avoid unnecessary delays should the site be considered for more sensitive uses in the future (e.g., residential, school day care, health care, etc.).

The long-term isolation of contaminated soil under pavement, buildings or some other type of caps should be avoided if at all possible. Leaving contaminated soil in place at a site imposes significant and oftentimes unnecessary burdens on future use and development of a site. This may be unavoidable, however, for soil contaminated with chemicals that require treatment and disposal at off-island, hazardous waste facilities (e.g., dioxins). If done, actions to prevent future disturbance of the soil should be clearly described in an *Environmental Hazard Management Plan* prepared for the site (refer to Chapter 5). The need for a formal covenant to the property deed should be also discussed with HDOH (generally not required for petroleum-contaminated soil or groundwater). A foresighted approach in the use of Tier 1 EALs or alternative, site-specific cleanup levels will allow more flexibility in future use of a site, help avoid unexpected complications during site redevelopment, and minimize the liability of future land owners.

2.10 Cumulative Risks at Sites with Multiple Chemicals of Concern

Risks posed by direct exposure to multiple chemicals with similar health effects are considered to be additive or "cumulative." For example, the total risk of cancer posed by the presence of two carcinogenic chemicals in soil is the sum of the risk posed by each individual chemical. The same is true for chemicals that cause noncarcinogenic health effects. A summary of example target health effects for the chemicals listed in the lookup tables is provided in Appendix 1 (Table K).

The Tier 1 EALs assume that no more than three carcinogenic COPCs, and no more than five noncarcinogenic COPCs, are present at a site. This is based on a combination of conservative exposure assumptions and target risk factors in direct-exposure models. Refer to Chapter 4 and Appendix 1 for additional discussion of this subject. The cumulative health risk may need to be calculated for sites where additional contaminants are present (see also USEPA 2008a).

2.11 Chemicals Not Listed in Lookup Tables

Compilation of action levels for chemicals not listed in the current lookup tables is a relatively straightforward process, provided that adequate supporting data are available. A detailed discussion of the development of action levels presented in this guidance is provided in Appendix 1. A summary of the approaches used to develop the action levels is provided in Figure 2-5. To compile action levels for

chemicals not listed in the lookup tables, the interested party should use the same approaches or contact the HEER office for assistance.

With the exception of the target, indicator compounds noted in Figure 2-4 and discussed in Section 2.6, 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., refer to NEIWPC 2003, included in Appendix 7).

Action levels must be developed for all applicable, potential hazards (refer to Sections 1.2 and 2.3). **In particular, the USEPA Regional Screening Levels (RSLs, USEPA 2008a) or the Preliminary Remediation Goals (PRGs) previously published by USEPA Region IX (USEPA 2004) cannot be used as stand alone criteria for the evaluation of contaminated soil** (refer also to Section 2.12.1). This is because the RSLs and PRGs do not consider all potential environmental hazards posed by contaminated soil. In particular, the RSLs do not address potential vapor intrusion ecotoxicity and gross contamination hazards. The PRGs (no longer in use by USEPA as of May 2008) have similar shortcomings but likewise do not fully address potential soil leaching hazards.

2.12 Comparison to Other Published Screening Levels

The *Summer 2008* edition of this guidance document represents the fourth update to a document originally published by HDOH in 1995 (HIDOH 1995) and more recently in May 2005. Similar guidance documents have been prepared by the same author for the California Environmental Protection Agency (CalEPA 2005a), the Commonwealth of the Northern Mariana Islands (CNMI 2005) and the Guam Environmental Protection Agency (GEPA 2008). Each of these guidance documents represent a progressive compilation and expansion of approaches developed by various environmental agencies in the USA, Canada and other countries. As discussed below, the documents incorporate and significantly expand on the USEPA *Preliminary Remediation Goals* and more recent *Regional Screening Levels* (USEPA 2004, 2008a). Differences and similarities between this guidance document and guidance prepared by the other agencies are summarized below.

2.12.1 USEPA RSLs and PRGs

The 2008 U.S. Environmental Protection Agency (USEPA) *Regional Screening Levels* (RSLs; USEPA 2008a) replace *Preliminary Remediation Goals* (PRGs) previously published by individual regions. This includes PRGs published by USEPA Region IX (USEPA 2004) and referenced in earlier editions of the HDOH environmental action level guidance. Like the PRG guidance, the RSL guidance presents risk-based soil, air and tapwater screening levels for a long list of contaminants.

The RSL and PRG models used are essentially identical, with the exception that the 2008 RSLs utilize Unit Risk Factors (cancer concerns) and Reference Concentrations (noncancer concerns) for inhalation of vapors and particulates, rather than Cancer Slope Factors and Reference Doses derived from the former as done in previous editions of the USEPA Region IX PRGs. This does not make a significant difference in the final screening levels. The 2008 USEPA RSL guidance also includes soil screening levels for potential leaching hazards (organic compounds only). Both the direct-exposure and leaching based screening levels take equal precedence.

The USEPA RSL direct-exposure models for soil and for tapwater were retained for use in this document. With the exceptions noted below and in Appendix 1, target risks, toxicity factors and physiochemical constants included in the RSL guidance were also retained for development of HDOH EALs.

The HDOH EALs represent a significant expansion of the USEPA RSLs to address a more comprehensive suite of environmental hazards potentially associated with contaminated soil and groundwater (refer to Section 1.2). Specific differences include (see Appendix 1 for details):

- Adjustment of soil direct-exposure RSLs for noncarcinogens to a target hazard quotient of 0.2, rather than 1.0, to address potential cumulative health concerns at sites where multiple contaminants are present;
- Extrapolation of inhalation toxicity factors from oral toxicity factors for volatile chemicals in cases where the former are not included in the RSLs (follows approach used in previous editions of the USEPA Region IX PRGs);
- Addition of direct-exposure action levels for construction and trench worker exposure to contaminated soils;
- Addition of soil, groundwater and soil gas action levels for vapor intrusion (indoor-air impact) hazards;
- Addition of groundwater action levels for the protection of aquatic habitats

and surface water quality (discharges of contaminated groundwater to surface water);

- Use of a more rigorous leaching model to develop soil action levels for protection of groundwater quality (soil leaching hazards);
- Addition of soil action levels for terrestrial ecotoxicity hazards in urban areas;
- Addition of soil and groundwater "ceiling levels" to address gross contamination hazards, including explosion hazards, odors, sheens and general nuisance and resource degradation concerns;
- Inclusion of soil action levels for arsenic and total chromium based on natural background; and
- Addition of soil and groundwater action levels for Total Petroleum Hydrocarbons (TPH).

Use of the USEPA RSL models in the HDOH EALs is discussed further in Chapter 3 of Appendix 1. **It is important to understand that the USEPA RSLs cannot be used as stand-alone screening levels to evaluate potential environmental hazards posed by contaminated soil and groundwater.** This is clearly stated in the User's Guide to the RSLs but often ignored in practice, especially at sites that fall under Federal rather than State jurisdiction.

2.12.2 Pacific Basin (Guam EPA) ESLs

Guidance published for the Guam Environmental Protection Agency in April 2008 was used as a template for the 2008 update to the HDOH guidance (GEPA 2008). The two documents are for the most part identical. The Guam EPA guidance uses the term *Environmental Screening Levels* (ESLs) rather than *Environmental Action Levels* (EALs), as preferred in Hawai'i. Unlike the Guam EPA guidance, the Hawai'i guidance has historically *not* provided a separate set of action levels for commercial or industrial properties in the summary, Tier 1 lookup tables. Tier 1 EALs are instead based purely on assumed unrestricted ("residential") use of a property. This was done to minimize restrictions on the future use of properties, as well as due to limited resources within the HEER office for the review of site-specific, human health risk assessments based on alternative land use scenarios. An alternative to select EALs for commercial/industrial land use only is, however, built into the HDOH 2008 EAL Surfer.

The Guam EPA Tier 1 lookup tables also include alternative soil screening levels for deep or otherwise isolated soils versus soils that are currently exposed at the ground surface or could be exposed at some time in the future. This reflects an assumption that residents and workers are not likely to come into regular contact with contaminated soils located more than three to four meters below the ground

surface. While this is option is not directly incorporated in the HDOH Tier 1 EAL lookup tables, the isolation of contaminated soils can be considered under a more advanced, *Environmental Hazard Evaluation* (refer to Chapter 4).

The HDOH guidance incorporates alternative, less stringent groundwater action levels for threats to aquatic habitats for sites situated greater than 150m from a surface water body (acute versus chronic surface water goals, refer to Section 2.4.4 and Figure 2.1). This recognizes the presence of lower permeability, “caprock” sediments over much of the low lying areas of the islands. The low permeability of the caprock sediments significantly impedes groundwater flows and the spread of contaminants away from the original release areas. This decreases the threat posed by the potential discharge of contaminated groundwater into streams and the ocean. These geologic conditions do not apply to Guam and alternative, less stringent groundwater screening levels for inland areas are not considered in the Guam EPA guidance. The Guam guidance represents an update to similar guidance prepared for the Commonwealth of the Mariana Islands (CNMI 2005).

The April 2008 Guam EPA ESLs for direct-exposure hazards do not incorporate USEPA’s changes to the calculation of soil direct-exposure actions levels published in the May 2008 RSL guidance. It is anticipated that changes will be incorporated into the Guam Guidance in the summer of 2008.

2.12.3 TSCA PCB Standards

Risk-based soil screening for polychlorinated biphenyls (PCBs) are included in the lookup tables of this guidance (refer to Table K series in Appendix 1). The action levels are calculated based on the same approach used to develop the USEPA Region IX PRGs and more recent USEPA RSLs, with the exception of the use of a target excess cancer risk of 10^{-5} rather than the default of 10^{-6} (refer to Section 1.3 in Appendix 1).

The treatment, storage and disposal of PCBs is also regulated under the Toxics Substance Control Act (TSCA), as described in Title 40, Part 761 of the Code of Federal Regulations. Reviews of TSCA regulations are provided in the USEPA documents *Guidance on Remedial Actions for Superfund Sites with PCB Contamination* (USEPA 1990) and *PCB Site Revitalization Guidance Under the Toxics Substances Control Act* (USEPA 2005). TSCA cleanup regulations are primarily targeted to address spills from operating electrical equipment. TSCA requirements are applicable to materials that contain PCBs in concentrations equal

to or great than 50 mg/kg, including soil. Impacted soils containing less than 50 ppm PCBs are not regulated under TSCA, provided that the concentrations are "as found" at the site and the impacted soil has not been mixed with clean soil to reduce total concentrations. *Soils containing PCBs at a concentration greater than 50 mg/kg must be treated and disposed of in accordance with TSCA regulations.*

TSCA regulations present several cleanup standards for PCBs in soil. In general, these cleanup standards are not applicable to sites that are not strictly regulated under TSCA. The cleanup standards primarily apply to spills within and around electrical substations and should not be applied in general to residential or commercial/industrial sites that are found to be contaminated with PCBs. For example, a TSCA cleanup standard of 1.0 mg/kg is often quoted for PCBs in residential areas. This "cleanup level," presented in 40CFR761 Subpart G for "high occupancy areas" (defined as >6.7 hours exposure per week) is based primarily on laboratory detection levels for PCBs in the 1980s and not strictly risk-based, nor does it reflect currently used toxicity factors for PCBs. Although almost identical to the residential action level for PCBs in soil of 1.1 mg/kg presented in the EALs (refer to Table K-1 in Appendix 1), *the TSCA cleanup level of 1.0 mg/kg is not technically supportable and cannot be referred to in soil cleanup actions for unrestricted (e.g., residential) land use.*

TSCA regulations also present a soil cleanup of 25 mg/kg PCBs in "low occupancy areas" (defined as <6.7 hours exposure per week). This cleanup level is presented under "Requirements for decontaminating spills in other restricted access areas." TSCA defines a "restricted access area" as a "...fenced or walled in area" associated with the spill of PCBs in or around an electrical substation or similar area ((40 CFR 760.125(c)(3)). If this doesn't apply to your site, neither does the TSCA cleanup level of 25 mg/kg. *For commercial/industrial sites in general, the TSCA soil cleanup level of 25 mg/kg is not applicable.*

The TSCA cleanup levels are intended to prevent the buildup of high concentrations of PCBs in areas where electrical workers may be exposed to spills on a regular basis (e.g., around transformers and other electrical equipment). They were not intended for use as cleanup levels in residential or commercial/industrial areas where PCB containing equipment is no longer being used or was never used. As described in the Toxics Substances Control Act (TSCA) regulations (40 CFR 761.120(e)(2)), the PCB cleanup levels presented were developed assuming "...(worker) exposures associated with ...typical, electrical equipment-type spills..." This can reasonably be interpreted to refer to

isolated and localized leaks and spills related to the normal operation of transformers and other electrical equipment.

TSCA regulations also clearly state that "EPA foresees the possibility of exceptional spill situations in which site-specific risk factors may warrant additional cleanup to more stringent numerical decontamination levels than are required by (the TSCA) policy (40 CFR 761.120(b))." For this reason and as summarized above, *the EALs for PCBs presented in the lookup tables of this guidance document take precedence in all soil cleanup actions not associated with the normal, ongoing operation of transformers and other electrical equipment.*

2.12.4 Hazardous Waste TCLP Standards

Waste is classified as either "hazardous" or "nonhazardous" in part based on Toxicity Characteristic Leaching Procedure (TCLP) analysis for solids and associated TCLP leachate standards (USEPA 1990). The TCLP leachate standards are intended to determine the type of landfill a waste material must be sent to (USEPA Title 22, Section 66699 - Persistent and Bioaccumulative Toxic Waste). If TCLP standards are exceeded, the waste must in general be sent to a Class I, hazardous waste landfill.

The TCLP test and associated leachate standards **cannot** be used screen soils for potential environmental hazards, including potential leaching hazards. The criteria, developed in the 1980s, are only loosely based on human health and environmental considerations and apply only to soil (and other materials) placed in a lined, regulated landfill. The TCLP test was not intended or designed to model leaching of contaminants from soil in the natural environment. Dilution attenuation factors assumed in the TCLP standards may not be applicable to settings outside of a landfill setting. Refer to Section 1.2 and Appendix 1 for guidance on appropriate methods for screening of contaminated soil and approaches for evaluation of potential leaching hazards.

2.12.5 OSHA Permissible Exposure Limits

The National Institute for Occupational Safety and Health (NIOSH) is the US Federal agency responsible for conducting research and making recommendations for the prevention of work-related disease and injury, including exposure to hazardous chemicals in air (NIOSH 2007). NIOSH develops and periodically revises Recommended Exposure Limits (RELs) for hazardous substances in the

workplace. The RELs are used to promulgate Permissible Exposure Limits (PELs) under the Occupational Safety and Health Act (OSHA).

In most cases, OSHA PELs are not appropriate for health risk evaluations for commercial settings where the chemical is not currently being used as part of a regulated, industrial process. This includes sites affected by the migration of offsite releases (e.g., via emissions from a moving plume of contaminated groundwater). OSHA PELs are derived for an occupational setting, where the chemical in question is used in the industrial process, i.e., workers and others who might be exposed to the chemical have knowledge of the chemical's presence, receive appropriate health and safety training, and may be provided with protective gear to minimize exposures. OSHA PELs are derived for adult, healthy workers and are not intended to protect children, pregnant women, the elderly, or people with compromised immune systems.

As one example, the current OSHA PEL for tetrachloroethylene (PCE) is 678,000 $\mu\text{g}/\text{m}^3$ (100 ppmv, NIOSH 2007). Comparable risk-based action levels for commercial/industrial exposure settings included in this document fall between 0.68 $\mu\text{g}/\text{m}^3$ and 10 $\mu\text{g}/\text{m}^3$ (carcinogenic effects vs noncarcinogenic effects, respectively; refer to Table E-3 in Appendix 1). The PEL is applicable to regulated work areas where PCE is being used and the employees have been properly trained to minimize exposure. The risk-based action levels for indoor air presented in this guidance document are applicable to all other areas.

Table 2-1. Additional Soil Action Levels for Areas of High Rainfall (>200 cm/year).

Soil Leaching Action Levels				
CONTAMINANT	Drinking Water IS Threatened		Drinking Water NOT Threatened	
	A-1 (Surface Water Within 150m)	A-2 (Surface Water NOT Within 150m)	B-1 (Surface Water Within 150m)	B-2 (Surface Water NOT Within 150m)
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
Benzene	2.0E-03	2.0E-03	1.8E-02	6.8E-01
Ethylbenzene	2.8E-02	2.8E-02	2.7E-01	2.8E-01
Toluene	1.0E-01	1.0E-01	3.4E-01	1.0E+00
Xylenes	2.0E-03	2.0E-03	1.0E-02	2.0E-01
Carbon Tetrachloride	2.4E-02	2.4E-02	4.7E-02	1.3E-01
Chlorobenzene	1.3E-02	2.5E-02	1.3E-02	8.0E-02
Chloroform	6.3E-02	6.3E-02	3.9E-01	1.5E+00
Methylene Chloride	2.4E-03	2.4E-03	1.2E+00	2.9E+00
Tetrachloroethylene	4.0E-02	4.0E-02	8.7E-01	8.7E-01
Trichloroethane	1.0E-02	3.3E-02	1.0E-02	1.0E+00
Trichloroethylene	7.1E-03	7.1E-03	1.4E-01	1.4E-01

Notes:
Reference: Table E-2 in Appendix 1. Based on greater potential for groundwater impacts due to increased leaching of contaminants from soil.
Soil leaching action levels only generated for common, mobile contaminants modeled in 1996 HDOH RBCA document.

3

Environmental Hazard Evaluations

3.1 Steps to Environmental Hazard Evaluation

Environmental Hazard Evaluation (EHE) ties site investigation activities to remedial actions (refer to Figure 1-1). During this stage of the environmental response process, data collected at the site are reviewed and potential environmental hazards posed by contaminated soil and groundwater are identified and evaluated (Figure 3-1). In most cases this will be a relatively simple task and the text of the evaluation itself will be very brief. Although not required, preparation of the EHE is greatly simplified by comparison of the site data to Tier 1 Environmental Action levels (Tier 1 EALs) and in particular by use of the EAL Surfer.

It is important to begin to identify potential environmental hazards at a site as soon as initial soil, groundwater and other data are received. This is used to guide completion of the site investigation as well as initiate discussions regarding the need for remedial actions. Questions that should be considered as part of the EHE include:

- 1) Of the initial list of contaminants of potential concern, which contaminants pose potential environmental hazards under uncontrolled site conditions?
- 2) What are the specific environmental hazards posed by these contaminants?
- 3) Are additional site data needed to better define the extent and magnitude of contamination or the potential 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) Are remedial actions required to address the hazards?

Answering these questions is not as difficult as it may at first seem and does not require a significant amount of technical expertise in the field of “risk assessment.” Approaching the EHE in a step-wise fashion will ensure that all potential environmental hazards are adequately considered and that the most cost-effective and appropriate remedial actions are selected.

3.1.1 Identify Contaminants of Potential Concern

Contaminants of potential concern (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 TPHgasoline, BTEX, naphthalene, lead and fuel oxygenates (refer to Figure 2-4). 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. Chapters 2 and 4 provide additional guidance for petroleum- and pesticide-contaminated sites.

The list of contaminants of potential concern can be quickly narrowed down once representative initial data are obtained by comparing the data to the HDOH Tier 1 Environmental Action levels (Tier 1 EALs, refer to Chapter 2). If the representative concentration of a contaminant does not exceed the corresponding 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, as described below.

3.1.2 Identify Potential Environmental Hazards

A summary of common environmental hazards posed by contaminated soil and groundwater is provided in Chapter 1 (see also Figures 1-1 and 1-2). A detailed evaluation of each environmental hazard on a site-specific basis would be an arduous and time consuming task. Fortunately, this level of effort will rarely be necessary. As discussed in Chapter 1, a simple comparison of site data to the Tier 1 EALs offers a relatively rapid and cost-effective alternative to detailed environmental hazard evaluations and related risk assessments. Use of the EAL Surfer included with this guidance to identify potential environmental hazards and expedite Tier 1 EHEs is highly recommended.

Example printouts of the EAL Surfer are provided in Figures 3-2a (data input form), 3-b (detailed environmental hazards) and 3-2c (EHE summary report). To use the Surfer, select the appropriate site scenario information from the pull-down list (groundwater utility, depth to top of contaminated soil and land use), select the target contaminant, and (optional) input the representative concentration of the contaminant in soil or groundwater (Figure 3-2a). Note that soil action levels for direct exposure, vapor intrusion and gross contamination hazards are higher (i.e., less stringent) for commercial/industrial land use than for unrestricted (“residential”) land use. Soil action levels for leaching hazards are unchanged since, in the absence of required, engineered controls (e.g., pavement over contaminated areas), use of the land for residential versus commercial purposes in itself does not necessarily alter the threat to groundwater.

The Surfer will generate Tier 1 EALs for the selected chemical and site scenario. If included, the Surfer will also indicate if the input soil and/or groundwater concentration exceeds the Tier 1 EALs. The input concentrations are compared to action levels for specific environmental hazards in the second worksheet (Figure 3-2b). 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 for the site (Figure 3-2c).

The example presented in Figures 3-2a, b and c is based on an assumed residential land use scenario with contaminated soil situated less than three meters below the ground surface (“shallow soils”). Groundwater is a current or potential source of drinking water. In the example, the input concentrations of benzene in soil (5.1 mg/kg) and in groundwater (150 µg/L) cause the Tier 1 EALs for both media to be flagged (Figure 3-2a). A look at the detailed action levels worksheet (Figure 3-2b) indicates that benzene in soil at the input concentration could pose soil direct exposure, vapor intrusion and leaching hazards. Groundwater contaminated with 150 µg/L benzene poses drinking water toxicity concerns but no other potential hazards. These potential hazards are summarized in the Summary EHE Report worksheet of the Surfer. This worksheet can be printed and included in the appendices of the formal EHE, with a brief discussion of the potential environmental hazards flagged and recommended followup actions included in the text of the report. Recall that this does not necessarily mean that the contamination does in fact pose the hazards indicated, only that the potential exists and that additional evaluation is warranted.

3.1.3 Complete the Site Investigation

The objective of the site investigation is to determine the extent and magnitude of contamination to the degree needed for adequate identification of potential environmental hazards. Determining the extent of contamination to “non-detect” levels of targeted COPCs is rarely necessary. Site investigation activities can be considered complete when the vertical and lateral extent of contamination above Tier 1 EALs is determined. In some cases (e.g., investigation of commercial/industrial areas with land use restrictions), the delineation of contamination to higher action levels is acceptable. Be aware that the distribution of contamination could be discontinuous. For example, irregular pulses of releases over time can result in groundwater plumes that taper off to less than EALs with increasing distance from the source and then rise again, as an older slug of contaminants is encountered.

The identification of potential environmental hazard(s) and completion of the site investigation is an iterative process. For example, if direct exposure to contaminated soil is flagged 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 specific spill areas is generally acceptable. This is because a person is assumed to have equal access (and therefore equal exposure) to all parts of the site, 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 collection of multi-increment sample data in specific exposure areas to better estimate exposure point concentrations should also be considered. As discussed in Chapter 4, the collection of bioaccessibility data for arsenic-contaminated soil is recommended when the concentration of total arsenic exceeds 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. Unlike direct exposure hazards, data collected outside of contaminated areas should *not* be considered when estimating representative soil concentrations. This is because the decision unit is the spill area, not the site as a whole, and the target “receptor” of concern is the groundwater that directly underlies the contaminated soil. If Tier 1 soil action levels for leaching concerns are exceeded then laboratory batch leaching test data can be collected for the target contaminants and a more advanced evaluation of leaching concerns carried out (refer to Chapter 4). Batch tests can also be used to confirm the cleanup of soils contaminated with chemicals that could threaten

groundwater resources. 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.

Soil or groundwater data flagged for potential vapor intrusion hazards almost always mean that soil gas samples should be collected at the site. The model used to develop the soil and groundwater actions levels for vapor intrusion estimate soil gas concentrations of the target contaminants based on assumed default soil properties and are considered to be conservative. Actual soil gas data for the site are much more reliable for evaluation of this hazard. The collection of methane data is also useful at sites with heavy petroleum contamination.

3.1.4 Evaluate Targeted Environmental Hazards

Potential environmental hazards flagged by comparison of site data to Tier 1 EALs (or approved alternative action levels) may or may not in fact exist at the site. The EALs intentionally assume uncontrolled current and future site conditions in order to minimize future restrictions on use of the property (i.e., unpaved, soil exposed at the surface, contaminants not strongly bound to soil, nearby aquatic habitats, etc.). Actual site conditions could differ, causing the contaminants to pose a much lower threat to human health and the environment than a simple, action level evaluation might imply. In these cases a more advanced and site-specific evaluation of targeted hazards is advisable and in some cases could even be required. Example approaches for evaluation of specific environmental hazards are provided in Chapter 4.

3.1.5 Identify Potential Additional Environmental Hazards

The EALs are intended to address common environmental hazards at sites where contaminated soil and groundwater are identified. The majority of these sites will be located in industrialized or urbanized areas where the threat to sensitive ecological habitats is limited. Additional, potential environmental hazards should be identified and evaluated as appropriate on a site-by-site basis (refer to discussion of EAL limitations in Section 1.6). This could include the runoff of contaminated soil into aquatic habitats and impacts on sediment quality, bioaccumulation of contaminants aquatic organisms, uptake of contaminants in produce, explosive hazards associated with methane buildup, etc. (refer also to Chapter 4 – *Advanced Environmental Hazard Evaluations*).

3.1.6 Prepare Environmental Hazard Maps

Question Five in Section 3.1 asks about the distribution of environmental hazards across the site. Instead of thinking in terms of contaminants and contaminant concentrations, it is now important to start thinking in terms of the actual hazards posed by the contaminants at the site. What areas of the site pose potential direct exposure or vapor intrusion hazards? What areas of the site pose potential leaching hazards? 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, since this understanding serves as the basis for cleanup decision-making as well as long-term management plans. For the latter, the preparation of post-cleanup, “as-built” *environmental hazard maps* is especially important. As discussed in the previous sections, this can be accomplished by comparison of site data to HDOH action levels (or acceptable alternatives) for targeted hazards. While not necessarily required to complete a project, such maps can help guide completion of and summarize the results of a site investigation, as well as assist those tasked with the preparation of remedial actions. A combination of contaminant distribution maps and environmental hazard maps may, however, be required for sites where contamination above action levels for unrestricted future use of the property is to be left in place and managed over time.

An example soil environmental hazard map (based on a former pesticide mixing area) where soil is contaminated with dioxin, arsenic, chlorinated pesticides, and heavy oil is presented in Figure 3-3. Areas of specific hazards were delineated by comparison of soil data to detailed environmental action levels (e.g., refer to HDOH EAL Surfer). Remedial options could vary with respect to the specific environmental hazard(s) posed in a given area. As an interim measure, contaminated soil that poses direct exposure hazards can be consolidated and placed under a well-managed soil cap. Areas of contaminated soil that pose leaching concerns will, in contrast, require some type of impermeable cap. Immediate removal of soil that is grossly contaminated with petroleum is recommended.

An example groundwater environmental hazard map is presented in Figure 3-4 (based after a former gasoline bulk fuel terminal). Contaminated soil has been removed. Remaining groundwater contamination poses several potential hazards, including vapor intrusion, toxicity to aquatic habitats, and gross contamination along the shoreline (odors and sheens). Areas of specific hazards were delineated

by comparison of groundwater data to detailed environmental action levels (e.g., refer to HDOH EAL Surfer). The site was to be redeveloped for residential use. Soil gas data confirmed potential vapor intrusion hazards. Aggressive treatment of the area of groundwater that posed vapor intrusion hazards was required prior to redevelopment. Aggressive remediation of groundwater that posed acute aquatic toxicity hazards and gross contamination (odors and sheens) within 50 meters of the shoreline was also required. Long-term monitoring of remaining groundwater contamination was required.

As described above, property owners, developers, and their consultants can utilize environmental hazard maps to help prioritize aggressive (and often costly) site cleanup actions by focusing resources on the most pressing hazards first. In many cases this may permit redevelopment of the site prior to the completion of final cleanup actions and the generation of funds to address remaining environmental hazards through less aggressive and presumably less costly measures (e.g., focused treatment of hot spots, in situ treatment of remaining groundwater contamination, long-term monitoring, institutional and engineering controls, etc.).

3.1.7 Recommend Followup Response Actions

Determining the most appropriate response to address environmental hazards at contaminated sites depends on a number of factors, including the presence or absence of hazards under current conditions, the planned future use of the site, the cost-benefit of postponing cleanup until a later time, natural attenuation of contaminants over time, regulatory requirements, etc. A partial list of potential recommendations is provided under Item 7 in Section 3.2. Refer also to advanced environmental hazard evaluation approaches discussed in Chapter 4.

Preparing a simple summary of environmental hazards posed under current site conditions versus unrestricted site conditions can aid in the selection of appropriate response actions. What types of environmental hazards could the contamination pose under uncontrolled site conditions? What controls are currently in place to eliminate or reduce these hazards? What types of additional actions are needed to address existing hazards? What type of response actions are needed to fully eliminate the environmental hazards and allow unrestricted, future use of the site? What type of hazards will still be present at the site following the recommended response action in the absence of engineered or institutional controls? Do recommended controls need to be formally implemented at the site (e.g., via a covenant to the deed)? An example format for summarizing these issues is provided in Figures 3-5a (contaminated soil) and 3-5b (contaminated groundwater).

When practicable, full cleanup of contaminated soil and groundwater to permit future unrestricted use of the property is desirable. If full cleanup will not be carried out, 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 engineering controls must then be evaluated. These controls could include restrictions on activities such as excavation or well drilling, 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, *Environmental Hazard Management Plan*. The preparation of *Environmental Hazard Management Plans* is discussed in more detail in Chapter 5.

3.2 Preparation of Environmental Hazard Evaluation Reports

The *Environmental Hazard Evaluation* (EHE) should serve as "stand alone" report that provide a good summary of environment impacts at a site and the existing or potential hazards posed by the contamination. The report should include the following information:

1. Site Background
 - Describe past and current site uses and activities.
 - Describe reasonably anticipated future site uses and activities. (*Always* include a comparison of site data to EALs for unrestricted ("residential") land use to evaluate need for formal land use restrictions and other institutional and engineered controls; see Section 2.7).
2. Summary of investigations (including to-scale maps with a north arrow):
 - Identify all types of impacted media (soil, groundwater, surface water, etc.).
 - Identify all sources of chemical releases.
 - Identify initial chemicals of potential concern.

- Identify magnitude and extent of impacts that exceed EALs to extent practicable and applicable (include maps of site with isoconcentration contours for soil and groundwater as practicable).
 - Identify nearby groundwater extraction wells, bodies of surface water and other potentially sensitive ecological habitats.
 - Ensure data are representative of site conditions.
3. Applicability of Tier 1 EALs or alternative action levels:
- Do Tier 1 EALs exist for all chemicals of concern?
 - Does the site have a high public profile and therefore require a higher degree of decision confidence (including preparation of a detailed, human health risk assessment)?
 - Do soil and groundwater conditions at the site differ significantly from those assumed in development of the lookup tables (e.g., low pH at mine sites)?
 - Do impacts pose a heightened threat to sensitive ecological habitats (e.g., presence of endangered or protected species)?
 - Have more than three carcinogens or five chemicals with similar noncarcinogenic health effects been identified (excluding petroleum, see Section 2.8)?
 - Other issues as applicable to the site.
4. Selection of soil and groundwater categories:
- State the regulatory beneficial use of impacted or potentially impacted groundwater beneath the site; discuss the actual, likely beneficial use of groundwater based on measured or assumed quality of the groundwater and the hydrogeologic nature of the soil or bedrock containing the groundwater.

- Characterize the soil type(s) and location of impacted soil as applicable to the lookup tables (e.g., soil stratigraphy, soil texture and permeability, depth to and thickness of impacted soil, etc.).
5. Selection of EALs and comparison to site data.
- Summarize how Tier 1 EALs were selected with respect to the information provided above and additional assumptions as applicable.
 - Compare site data to the selected summary Tier 1 EALs (presented in Volume 1) and identify areas of soil or groundwater that pose potential environmental hazards.
6. Identification of potential environmental hazards:
- Identify specific, potential environmental hazards by comparison of site data to detailed EALs for individual hazards (use the EAL Surfer; detailed tables presented in Volume 2, Appendix 1).
 - Identify any additional, potential environmental hazards not specifically addressed by the EALs (refer to Section 3.1.5).
 - Consider presentation of environmental hazard maps in the EHE to help guide followup remedial actions and long-term site management plans.
7. Conclusions and recommendations for followup actions, possibly including (see also Section 3.1.6):
- Recommendation for no further action;
 - Recommendation for the collection of additional soil, groundwater and/or soil gas data to complete the site investigation and delineation of environmental hazards;
 - Recommendation for more advanced evaluation of specific, environmental hazards, including (refer to Chapter 4):
 - Use of SPLP batch tests to evaluate potential leaching hazards;

- Collection of soil gas data to better evaluate vapor intrusion hazards;
 - Testing of soil for bioaccessible arsenic data to better evaluate risk to human health;
 - Preparation of a tradition human health and ecological risk assessments to quantify risks to human and/or ecological receptors;
 - Field evaluation of potential gross contamination hazards;
 - Evaluation of free product mobility.
- Recommendation for preparation of a remedial action plan to address the identified environmental hazards;
 - Recommendation for land-use restrictions and/or institutional controls to address the identified environmental hazards in the absence of full cleanup to unrestricted land use (e.g., requirements for caps, etc.; formal land use restrictions, etc.).
 - Recommendation for preparation of an *Environmental Hazard Management Plan*.

The conclusions and recommendations of the EHE should be referenced in and used to develop the remedial action plan. For example, air sparging and soil vapor extraction could be the most appropriate remedy to address vapor intrusion hazards. *In situ* chemical oxidation may be effective in reducing non-urgent hazards associated with the contamination of marginal drinking water resources or potential discharges of contaminated groundwater to nearby aquatic habitats. Excavation could be the most cost-effective approach to address gross contamination hazards in soil within five meters of the ground surface. In-situ free product recovery could be appropriate of address deeper, gross contamination hazards at the groundwater interface. Capping with clean soil may be appropriate to address direct exposure hazards at sites where the soil cannot be removed. Capping with pavement or some other type of impermeable barrier would be required for soil that poses potential leaching hazards.

The above elements are not intended to be exhaustive or representative of an exact outline required for all Tier 1 EHEs. The level of detail required for an EHE will vary at individual sites. For relatively simple sites, the EHE can be included as a separate chapter in the post-remediation report with EAL Surfer printouts for target COPCs included in the appendices. Preparation of a separate EHE that serves as a stand-alone summary of site conditions may be more appropriate for complicated sites. As discussed above, both maps that summarize the extent and magnitude of contamination as well as maps that depict areas of specific environmental hazards (or some combined form of the maps) are very useful components of EHEs. This information may then be passed on to persons developing remediation action plans for active cleanup of contaminated areas and/or *Environmental Hazard Management Plans* for long-term management of sites that cannot be fully cleaned up.

Conditions that pose immediate or short-term environmental hazards should be addressed as quickly as possible. This includes exposure of residents or workers to potentially harmful levels of contaminants in soil (“direct exposure”), impacts to water supply wells, intrusion of vapors or methane into overlying structures (including explosion hazards) and discharges of free product to surface water.

The approach described in this chapter was referred to as Environmental “Risk Assessment” and in previous editions of this guidance (e.g., HDOH 2005). The term “risk assessment” is replaced with the term “hazard evaluation” in this edition of the guidance document. This was done in part to reflect the fact that the guidance was prepared by the *Environmental Hazard Evaluation* section of the HDOH HEER office. This was also done to help distinguish an EHE from a traditional human health and ecological risk assessments. Human health and ecological risk assessments can of course be included as one component of an *Environmental Hazard Evaluation*, but they cannot be used as stand-alone tools to determine the need for potential cleanup actions at sites where petroleum-contaminated soil and groundwater are identified (refer to Section 1.2). Additional information on human health and ecological risk assessments is provided in Chapter 4.

4

Advanced Environmental Hazard Evaluations

4.1 Tentatively Identified Environmental Hazards

Use of the Tier 1 EALs allows for the expedited identification of contaminated soil and groundwater that could, under some site conditions, pose a significant threat to human health and the environment. This approach allows sites with minimal contamination to be quickly investigated and remediated as needed, without the need for costly and time consuming risk assessments and other evaluations of potential environmental hazards.

A more advanced evaluation of potential environmental hazards should be considered as cost of remedial actions or the imposition of engineered or institutional controls begins to pose a significant burden on the responsible party or property owner. A summary of possible approaches is provided in Figures 4-1a (soil) and 4-1b (groundwater). Examples include:

- Use of bioaccessibility tests to estimate the potentially toxic fraction of total arsenic in soil. Bioaccessibility tests carried out on soils from former agricultural areas in Hawai'i typically indicate that 80-90% of the arsenic is so tightly bound to the soil that it is essentially nontoxic. This can significantly reduce or even eliminate the need for capping or aggressive treatment of contaminated soil. (Note that much higher bioaccessibilities have been identified in non-agricultural soils that lack high concentrations of iron, e.g. carbonaceous soils in caprock areas.)
- The necessity and practicability of removing gross contamination in areas where access is limited and no other environmental hazards are posed should be evaluated on a site-by-site basis. Targeted removal of free product can be based

on an evaluation of the stability, potential mobility and recoverability of the product (e.g., ASTM 2006).

- Long-term monitoring of petroleum-contaminated groundwater is likely to indicate that the groundwater contaminant plume will rapidly shrink once the source of the release and gross contamination is removed (see Chapter 5). This can be used to support a remedy of focused, aggressive treatment in the immediate release area and natural attenuation as the selected remedy in outer areas of the plume.
- Soil gas data provide a much more realistic idea of vapor intrusion hazards initially flagged by a comparison of soil or groundwater data to Tier 1 action levels for this concern. Collection of soil gas data and comparison to action levels for potential vapor intrusion hazards will expedite the identification of buildings or even specific areas of buildings at high risk for potential indoor air impacts (see Table E).
- If direct-exposure to contaminated soil is the driving environmental hazard at a site and the contamination cannot be cost-effectively removed, then placement of a restriction on future land use can reduce or even eliminate the need for aggressive remedial actions (e.g., commercial/industrial land use only).

Although “advanced,” these and other approaches for a more site-specific review of potential environmental hazards flagged during the Tier 1 environmental hazard evaluation are not necessarily costly and do not necessarily require a significantly greater amount of technical expertise.

These and other example approaches for more advanced evaluations are outlined below. These evaluations can be relatively simple, such as the use of groundwater monitoring data to evaluate leaching and plume migration hazards or soil gas data to better evaluate vapor intrusion hazards. Other approaches can be very time-consuming and do require more technical expertise, such as the preparation of a human health or ecological risk assessment.

A brief overview of human health risk assessments and ecological risk assessments are provided at the end of this section. Although the nomenclature and intent of the two types of documents is often confused, it is important to understand that a traditional human health risk assessment *cannot* be used in place of an *Environmental Hazard Evaluation*. Human health risk assessment focuses

on toxicological risks to humans associated with direct exposure to contaminated soil, groundwater, or air. While these risks are important, direct exposure is only *one* of several potential environmental hazards that are addressed in a more comprehensive EHE (refer to Section 1.2). Action levels specifically developed to screen for potential direct exposure concerns are incorporated in the Tier 1 EALs (based on USEPA Regional Screening Levels, see below). Preparation of a traditional, human health risk assessment is generally only necessary at sites where exposure of residents or workers to contamination above target, risk-based action levels is taking place and cannot be immediately remedied or where significant contamination is to be managed in place in residential or other sensitive use developments (schools, day care centers, medical facilities, etc.; refer to Section 4.2.1.3). In some cases, legal needs on the part of the responsible party could also require preparation of a detailed human health risk assessment.

4.2 Advanced Evaluations of Contaminated Soil

Example approaches for advanced evaluation of environmental hazards posed by contaminated soil are presented in Table 4-1a. A brief discussion of highlighted topics is provided below.

4.2.1 Direct Exposure

4.2.1.1 Tier 2 Direct Exposure Model

This guidance document includes an easy-to-use, Excel-based spreadsheet model (available for download from HDOH HEER office webpage) that calculates site-specific, Tier 2 direct-exposure action levels for soil based modifications to default site conditions and human exposure assumptions. The model uses the same equations used to develop the USEPA Regional Screening Levels and the Tier 1 action levels for direct exposure hazards (refer to Appendix 1). Printouts of the model input pages (first two worksheets, two pages) should be included in the Environmental Hazard Evaluation. All changes made to default input parameter values must be discussed and supported in the text of the report.

A copy of the first page of the model is provided in Figure 4-2. To use the model, simply select the contaminant of concern, select the land use exposure scenario, and adjust the soil parameter values as appropriate based on site data. Assumed soil properties typically have very little effect on calculated direct-exposure action levels. An exception is the input thickness of contaminated soil for volatile chemicals. The USEPA source model assumes that the emission of a volatile

chemical from contaminated soil remains constant over the entire 30-year exposure period (USEPA 1996, 2008a). This constant emission progressively depletes the mass of the chemical in the soil over time. For highly volatile chemicals such as vinyl chloride and even benzene, maintaining the model's theoretical vapor emission rate over 30 years would require the volume of contaminated soil to be tens of meters thick. This is not realistic for most sites.

The Tier 2 direct-exposure model includes an alternative, "mass-balanced" volatilization factor that establishes a maximum, long-term vapor emission rate based on the mass of contaminant present and the assumed exposure duration (default exposure duration = 30 years, USEPA 1996). To adjust the soil action levels simply input the site-specific thickness of soil above Tier 1 EALs. The spreadsheet automatically generates an adjusted, Tier 2, direct-exposure action level for the selected land use. An action level is also generated for construction worker exposure. If the latter is lower than the Tier 2 action level for the selected exposure scenario then it is selected as the final, action level. Risk-based soil action levels for construction workers can in particular be more stringent than those for commercial workers at sites where soils are contaminated with metals that are highly toxic via inhalation in dust (e.g., beryllium, Cr VI, cobalt, etc.; refer to Table K-2 in Appendix 1).

Changing the input site parameters beyond the assumed exposure scenario will have very little effect on action levels for nonvolatile chemicals. This is because the thickness of contaminated soil at a site (or more correctly the mass of the contaminant present) does not play a significant role in estimating the risk or calculating soil action levels for nonvolatile contaminants. Exposure assumptions (exposure duration, target risk etc.) can be adjusted in the spreadsheet. However, most of these assumptions are essentially "fixed" for the noted exposure scenario and will require review by a toxicologist for approval.

4.2.1.2 Tier 2 Action levels for Arsenic, Dioxin and Technical Chlordane

The HDOH published a series of technical memorandums between 2005 and 2008 that provide alternative, Tier 2, direct exposure action levels for arsenic, dioxin and technical chlordane in soil (HDOH 2006a, 2006b and 2007a). Copies of the technical memorandums are provided in Appendix 8. The information in these memorandums is restated and updated below. Use of the alternative approaches presented is recommended. The action levels are based on modifications to the USEPA Regional Screening Levels used to develop Tier 1 action levels for direct exposure hazards (USEPA 2008a; refer also to Appendix 1).

The alternative action levels can be used in place of the Tier 1 EALs provided that other contaminants are not present above their respective Tier 1 (or Tier 2) action levels for direct-exposure hazards. If elevated levels of other contaminants are present, then the cumulative health risk posed by all of the contaminants should be estimated and evaluated in a site-specific, human health risk assessment. The use of soil contaminated with arsenic, dioxins and technical chlordane as daily (short-term) or interim (long-term) fill at landfills is discussed in the respective summary tables for each contaminant.

Potential leaching hazards posed by arsenic and chlordane should be evaluated separately. Although relatively immobile, these contaminants could pose potential leaching concerns under some conditions. Dioxins do not pose a potential leaching threat under any condition. Refer to Chapter 4 for guidance on the site-specific evaluation of leaching hazards.

Arsenic

A detailed discussion of Tier 2 action levels and guidance for arsenic is provided in Appendix 9 (HDOH 2008b; update to 2006 HDOH technical memorandum). A summary of the HDOH Tier 2 action levels and guidance for arsenic is provided in Figure 4-3a (unrestricted land use) and Figure 4-3b (commercial/industrial land use only). Total arsenic analyses should be used to initially screen soils for potential contamination concerns. If the reported total concentration of arsenic exceeds 20 mg/kg (assumed upper limit of natural background), then the samples should be tested for *bioaccessible* arsenic.

Bioaccessible arsenic is the fraction of the total arsenic in ingested soil that could be available for absorption by a person's digestive tract and pose health risks. Equivalent concentrations of bioaccessible arsenic in soil are calculated by multiplying the reported total concentration of arsenic by the fraction that is determined to be bioaccessible by site-specific bioaccessibility tests. Refer to the August 2006 HDOH technical memo provided in Appendix 8 for additional information. USEPA guidance for lead-contaminated soil calls for use of the <250 micron soil fraction in bioaccessibility tests (USEPA 2000). This also applies for bioaccessibility tests carried out on arsenic-contaminated soils.

The Tier 2 arsenic action levels do not consider potential leaching of arsenic from soil and subsequent impacts to groundwater. The use of laboratory batch tests to evaluate this potential hazard is recommended. Refer to Section 4.2.3 for additional information.

Dioxin

A detailed discussion of Tier 2 action levels and guidance for dioxins is provided in Appendix 9 (HDOH 2008c; update to 2006 HDOH technical memorandum). A summary of HDOH Tier 2 action levels for dioxins is provided in Figure 4-4a and 4-4b. Dioxins are contaminants of potential concern in former agricultural areas due to their presence as manufacturing-related impurities in pesticides, especially pentachlorophenol, 2,4,5-trichlorophenoxyacetic acid (2,4,5-T), and 2,4,5-trichlorophenoxypropionic acid (2,4,5-TP or Silvex). These pesticides were commonly used in sugar cane and other operations. Dioxins can also be created when organic material is burned in the presence of chlorine.

Quantification of dioxins in soil for use in human health risk assessments requires conversion of congener-specific GC/MS data to Toxicity Equivalent (TEQ) dioxin concentrations by use of Toxicity Equivalence Factors (TEFs; WHO 2005). The TEQ concentrations for individual congeners are then added together to calculate a total TEQ dioxin concentration for the sample. Tier 2 soil action levels presented in the HDOH guidance are applicable to adjusted TEQ dioxin data.

Laboratory bioassay methods offer a cheaper alternative for dioxin analysis in comparison to standard GC/MC methods (typically 50% or less than GC/MS; HDOH 2007a). Methods currently available include CALUX and Cape Technology's DF1 kit (refer to HDOH 2006a memo in Appendix 8), with CALUX currently in most use. Laboratory method procedures for CALUX have also been formalized (USEPA 2008b). A Bioassay data are reported directly in terms of TEQ concentrations and do not require conversion using congener-specific TEFs. Ten percent of the samples (minimum two per site) should be tested using GC/MS to confirm bioassay-based TEQ dioxin data. The GC/MS analyses should be conducted on samples with the highest-reported bioassay TEQ dioxin results.

Dioxins (and furans) are not considered to be significantly mobile in soil due to their strong sorption to organic carbon and clay particles ($k_{oc} > 30,000 \text{ cm}^3/\text{g}$; refer to Section 3.4 in Appendix 1). Consideration of soil leaching hazards is therefore not considered to be necessary. Pesticides associated with dioxins could pose potential leaching and groundwater contamination hazards, however, and should be included in testing and evaluation.

Technical Chlordane

A summary of HDOH Tier 2 action levels for Technical Chlordane is provided in Figure 4-5 (HDOH 2007a, Appendix 9). Soils adjacent to or under buildings that

are known or suspected to have been treated with termiticides should be tested for organochlorine pesticides before reuse in open exposed areas (USEPA Method 8081A, HDOH 2007a). For “chlordane,” the laboratory should report the total concentration of the *technical chlordane* mixture rather than individual chlordane isomers and related compounds found in the mixture (e.g., heptachlor). This must be specifically requested on the Chain of Custody form and discussed with the laboratory in advance. Laboratories should also be instructed to report any additional organochlorine pesticides that are not typically found in technical chlordane (e.g., DDT, dieldrin, endrin, etc.).

Technical chlordane is not considered to be significantly mobile in soil due to its relatively strong sorption to organic carbon and clay particles ($k_{oc} > 30,000 \text{ cm}^3/\text{g}$; refer to Section 3.4 in Appendix 1). Technical chlordane mixtures contain multiple compounds with differing degrees of potential mobility, however. Laboratory batch tests are therefore recommended to evaluate potential leaching hazards for soil that is to be left in place at a site with a representative concentration of technical chlordane that exceeds 15 mg/kg technical. Refer to Section 4.2.3 for additional information.

4.2.1.3 Human Health Risk Assessment

The preparation of a traditional, human health risk assessment may be required at heavily contaminated sites that are unlikely to be cleaned up in the near term and/or in cases where contamination is to be managed in place at sites being used for residential or other sensitive land use purposes (see Section 4.1). A detailed risk assessment is rarely required for petroleum-contaminated sites. An in depth review of the preparation of human health risk assessments is beyond the scope of this guidance document. Selected references for additional information are provided below:

- USEPA Regional Screening Levels: (USEPA 2008a).
- Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (USEPA 2002a);
- Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (USEPA 2002b);
- Assessing the Significance of Subsurface Contaminant Vapor Migration to Enclosed Spaces (Johnson et al. 1998, 2002);

- Exposure Factors Handbook (USEPA 1997a);
- Health Effects Summary Tables (USEPA 1997b);
- Superfund Soil Screening Guidance: Technical Background Document (USEPA 1996);
- Supplemental Guidance For Human Health Multimedia Risk Assessments of Hazardous Waste Sites and Permitted Facilities (CalEPA 1996);
- Standard Provisional Guide for Risk-Based Corrective Action (ASTM 1995);
- Preliminary Endangerment Assessment Guidance Manual (CalEPA 1994); and
- Risk Assessment Guidance for Superfund. Volume I, Human Health Evaluation Manual (Part A) (USEPA 1989a).

As discussed in Section 1.2, it is important to ensure that all potential environmental hazards are adequately evaluated at sites where human health risk assessments are carried out.

4.2.2 Vapor Intrusion into Buildings

Detailed guidance on advanced approaches for evaluation of vapor intrusion hazards is provided in Section 4.4. A more site-specific evaluation usually begins with the collection of soil gas data once concentrations of volatile contaminants in soil or groundwater exceed Tier 1 action levels for this potential hazard. The use of site-specific vapor intrusion models in the absence of soil gas data is strongly discouraged.

4.2.3 Leaching and Contamination of Groundwater

Soil leaching hazards drive the selection of final, Tier 1 EALs for the majority of organic contaminants presented in the lookup tables. That is, action levels for leaching hazards are lower than action levels for direct exposure, vapor intrusion, ecotoxicity and gross contamination hazards (refer to Tables A through D in Appendix 1). Leaching and contamination of groundwater resources will therefore be a common concern at most contaminated sites. In addition, action levels for leaching hazards are not incorporated into the Tier 1 EAL for metals,

since the existing models are very unreliable. If metals are suspected to be potentially mobile, this concern must be evaluated a site-by-site basis.

Laboratory batch tests are recommended for more site-specific evaluations of soil leaching hazards. Batch tests can also be used to confirm the cleanup of soils contaminated with chemicals that could threaten groundwater resources. A summary of this approach is provided in the Hawai'i Department of Health guidance document *Use of laboratory batch tests to evaluate potential leaching of contaminants from soil* (HDOH 2007b). Four basic questions are posed:

1. "Is the contaminant potentially mobile?"
2. "What is the concentration of the contaminant in leachate in the primary source area?"
3. "What is the concentration of the contaminant in leachate at the point that the leachate reaches the top of the water table?" and
4. "What is the concentration of the contaminant in groundwater after the leachate has impacted the groundwater?"

Each of these questions should be answered in a site-specific evaluation of potential soil leaching concerns.

The approach is relatively simple. As discussed in Chapter 1, decision units for contaminants that pose potential leaching hazards should be defined as specific spill areas (refer to Section 1.4). A representative sample is collected. The sample is tested for the target contaminant of potential concern. If the reported concentration of the contaminant exceeds the Tier 1 action level for leaching hazards, or if it is a potentially mobile metal, then a split of the sample is also tested using the Synthetic Precipitation Leaching Procedure (SPLP) batch test method. In this method, 100 grams of soil are placed in two liters of buffered, de-ionized water and the mixture is agitated for a set period of time. The ratio of the mass of contaminant that remains sorbed to the soil compared to the mass that goes into solution is the *desorption coefficient*, or K_d . If the K_d value is greater than 20, then the contaminant is considered immobile and no further action is required to address leaching hazards. If the K_d value is less than 20 then the estimated concentration of the contaminant in leachate and ultimately in groundwater is compared to target groundwater action levels and the need for further action is evaluated. (Note that direct comparison of SPLP data to target groundwater action levels is not technically correct or appropriate in most cases.)

A detailed discussion of the approach is provided in the referenced HDOH guidance (HDOH 2007b, included in Appendix 8). The guidance includes an easy-to-use, Excel-based spreadsheet model that can be used to calculate K_d values and estimate contaminant concentrations in leachate and groundwater (available for download from the HDOH HEER office webpage). A copy of the input page of the model is provided in Figure 4-6. **Use of batch tests to confirm the adequacy of soil action levels for leaching hazards and final cleanup actions is strongly recommended at sites that overlie highly valued and vulnerable groundwater resources.** Batch tests can be run on confirmation soil samples in conjunction with standard soil analyses at minimal added costs (including TPH).

4.2.4 Gross Contamination

Gross contamination of soil includes the presence of potentially mobile free product, offensive odors, unaesthetic appearance, generation of explosive vapors, and general resource degradation. Although it may seem counterintuitive, it is possible for soil to be so heavily contaminated with some chemicals that the soil is flammable but is not considered “toxic” in the classic toxicological sense. Acetone, methyl ethyl ketone, xylenes, and even gasoline (in the absence of significant benzene content) are a few examples. Gross contamination hazards generally drive cleanup of soil contaminated with these chemicals.

When gross contamination hazards are flagged in the Tier 1 Environmental Hazard Evaluation then a check of actual conditions in the field is strongly recommended. Soil heavily contaminated with diesel fuel may not pose a direct-exposure hazard but its presence at or near the surface in a new residential development would most likely not be welcome. Advanced evaluation of gross contamination hazards for potentially flammable or explosive contaminants can be carried out by the comparison of soil gas data to lower explosive limits for the target contaminants (refer to NIOSH 2007). Note that the OSHA PELs are not appropriate for evaluation of gross contamination hazards (refer to Section 2.10.5).

Both TPH and methane should be included in soil gas analyses for petroleum-contaminated sites (see Sections 2.4 and 4.4.4). Published guidance on the evaluation of methane hazards includes:

- CalEPA, 2005, *Advisory on Methane Assessment and Common Remedies at Schools Sites* (June 16, 2005) California Environmental Protection Agency, Department of Toxic Substances Control.

A copy of this guidance is provided in Appendix 8.

4.2.5 Terrestrial Ecotoxicity

Detailed, ecological risk assessments will not be required for the majority of sites overseen by HDOH. The need for a detailed evaluation of terrestrial ecotoxicity hazards should be based on an inspection of the site by a qualified individual and the identification of potentially threatened habitats and endangered or threatened species. Refer to the 2008 edition of the HDOH HEER Office *Technical Guidance Manual* for additional guidance on the preparation of ecological risk assessments.

4.3 Advanced Evaluations of Contaminated Groundwater

Example approaches for advanced evaluations of environmental hazards posed by contaminated groundwater are presented in Table 4-1b. A brief discussion of highlighted topics is provided below.

4.3.1 Drinking Water Resource Contamination

Action levels for drinking water are not easily adjustable. Toxicity-based drinking water action levels for approximately 40% of the chemicals listed in the lookup tables are based on promulgated standards and cannot be changed (refer to Appendix 1). Action levels for the remaining chemicals are based on a USEPA model for tapwater. The latter could in theory be adjusted based on alternative exposure assumptions and toxicity factors but the approach used is relatively straight forward and rigid and adjustment is considered unlikely. The same is true for drinking water action levels based on gross contamination, taste and odor concerns.

Site-specific evaluations of threats to drinking water resources should instead focus on plume mobility and the long-term persistence of the chemicals released. Nearby groundwater supply wells should be identified. Long-term monitoring should be carried out to assess plume mobility. Groundwater fate and transport models may be useful in some cases, but should not be relied upon in the absence of actual groundwater monitoring data and aquifer data. Petroleum plumes rarely migrate more than a few hundred feet from the release area. Persistent chemicals such as chlorinated solvents, MTBE, pesticides, and other persistent chemicals pose the greatest long-term threat to drinking water resources. In some cases, the

installation of sentinel wells between the contaminant plume and a threatened well may be required.

4.3.2 Vapor Intrusion into Buildings

Detailed guidance on advanced approaches for evaluation of vapor intrusion hazards is provided in Section 4.4. A more site-specific evaluation usually begins with the collection of soil gas data once concentrations of volatile contaminants in soil or groundwater exceed Tier 1 action levels for this potential hazard. The use of site-specific vapor intrusion models in the absence of soil gas data is generally discouraged.

4.3.3 Discharges into Aquatic Habitats

Fewer than 20% of the action levels for aquatic toxicity are based on promulgated surface water standards. While adjustment of non-promulgated actions levels based on alternative study data is feasible, it will rarely be required or beneficial.

As discussed for drinking water concerns, site-specific evaluations of threats to nearby aquatic habitats should instead focus on plume mobility and the long-term persistence of the chemicals released. Nearby, surface water bodies should be identified. Storm sewers and other potential conduits that cross through the plume should also be identified. Long-term monitoring with or without the use of fate and transport models (generally not necessary) should be carried out to assess plume mobility. If plumes are discharging into an aquatic habitat then a more detailed evaluation of surface water and groundwater interaction and impacts on aquatic organisms may be required.

Use of a generic dilution factor to adjust action levels for the protection of aquatic habitats is not recommended (refer to Chapter 2). This is because benthic organisms that live at the groundwater-surface water interface will not be protected by dilution of groundwater in the water column. Consideration of acute aquatic toxicity action levels may, however, be appropriate on a site-specific basis (e.g., discharges of groundwater into in highly developed, harbor areas without significant benthic habitats).

4.3.4 Gross Contamination

Gross contamination concerns for groundwater are primarily related to petroleum releases. Check for free product if solubility limits for target contaminants are

approached or exceeded. Check shoreline or stream bank areas beside areas of heavily contaminated groundwater for sheens, odors and related gross contamination concerns. Monitor soil gas for methane buildup and potential explosion hazards in areas of heavy petroleum contamination. Be sure to include TPH and methane in soil gas analyses (see Sections 2.4, 4.2.4 and 4.4.4).

4.4 Advanced Evaluation of Vapor Intrusion Hazards

4.4.1 Overview of Vapor Intrusion

Use of the soil, groundwater and soil gas action levels for vapor intrusion concerns presented in this guidance to initially screen sites contaminated with volatile contaminants is highly recommended. The significance of vapor intrusion hazards is closely tied to local climate conditions and building designs. The mild climate, lack of heating in buildings and general improved ventilation of buildings in Hawai'i significantly reduces vapor intrusion hazards in comparison to colder areas on the US mainland. Hawai'i-specific action levels for vapor intrusion hazards are correspondingly less conservative than actions levels used in colder areas.

Volatile organic chemicals (VOCs) can be emitted from contaminated soil or groundwater and intrude into overlying buildings, impacting the quality of indoor air. While actual impacts to indoor air can vary widely from building to building, and even within buildings, it is generally possible to estimate worst case scenarios for use in screening level risk assessments. Soil, soil gas, and groundwater action levels were developed for this purpose and incorporated into the EALs. A summary of approaches used to develop the action levels is included in Appendix 1.

Heating, ventilation, and air conditioning (HVAC) systems, basements, strong winds, and other factors can exacerbate vapor intrusion problems by reducing internal air pressure and creating a vacuum effect that enhances the advective flow of vapors through building floors (e.g., USEPA 2003, CalEPA 2004). For buildings with a slab-on-grade design, this can result in the direct flow of subsurface vapors into a building with little or no dilution beforehand. The vapors become diluted as they mix with fresh air being drawn in through the building's HVAC system or through open doors and windows, generally by a factor of 500 to 1,000 for residential buildings and higher for commercial/industrial buildings (see Appendix 1).

For buildings with a crawl space design, subsurface vapors are diluted as they diffuse into and mix with air in the crawl space below the building floor. Additional mixing may or may not occur as the air from the crawl space is pulled into the building. Vapor flux through the building floor could be significantly elevated in comparison to slab-on-grade design buildings due to the operation of an HVAC systems in poorly ventilated rooms (e.g., an unvented closet). This issue is still being evaluated. An initial review of published literature and site data, however, suggests that soil gas-to-indoor air attenuation factors for crawl space design buildings may be very similar to those for slab-on-grade design buildings.

The field of vapor intrusion investigations is still evolving. Approaches to site investigations and evaluation of vapor intrusion concerns presented in guidance documents noted above and discussed below should not be taken as stringent requirements that must be applied at all sites. Appropriate investigation and risk assessment needs should be determined on a site-by-site basis. Site-specific requirements could be less or more stringent than those presented.

Published guidance documents on vapor intrusion hazards and investigations include:

- USEPA: User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings (USEPA 2003 and updates),
- DoD: Tri-Services Handbook for the Assessment of the Vapor Intrusion Pathway (DoD 2008);
- California: *Guidance for the Evaluation of the Vapor Intrusion to Indoor Air Pathway* (CalEPA 2004);
- Massachusetts: *Indoor Air Sampling And Evaluation Guide* (MADEP 2002b);
- New Jersey: Vapor Intrusion Guidance, New Jersey Department of Environmental Protection (NJDEP 2005); and
- New York: *Guidance for Evaluating Soil Vapor Intrusion in the State of New York* (NYDEH 2006).

4.4.2 Collection of Soil, Groundwater and Soil Gas Data

4.4.2.1 Stepwise Approach to Vapor Intrusion Evaluation

The direct collection and analysis of indoor air samples may seem to be an easy way to evaluate vapor intrusion concerns. However, identification of the sources of VOCs identified is complicated by the presence of the same chemicals in auto emissions and in many household goods (aerosol sprays, dry-cleaned clothing, cleaners, etc.). For example, ambient levels of benzene in outdoor air in urban

areas (related to auto exhaust) typically exceed the indoor air action level presented in Table E ($0.085 \mu\text{g}/\text{m}^3$) by an order of magnitude or more. Ambient levels of dry cleaning solvent (tetrachloroethylene) and other chlorinated solvents in indoor air may also exceed the action levels presented in Table E.

As an alternative, the sequential collection and evaluation of groundwater data or soil data (see below), soil gas data and, if needed, indoor air data is recommended. These data can then be compared to action levels for vapor intrusion concerns presented in this document and areas of elevated concern quickly identified. The following approach is recommended (refer also to CalEPA 2004):

- 1) Compare soil and/or groundwater data to appropriate action levels for vapor intrusion concerns (see Tables E-1a and E-1b of Appendix 1 or the EAL Surfer); for sites with significant impacts to vadose-zone soils, proceed directly to Step 2;
- 2) For areas where action levels for vapor intrusion concerns are approached or exceeded or sites where significant releases to vadose-zone soils have occurred, collect shallow soil gas samples immediately beneath (preferred) or adjacent to buildings and compare results to soil-gas action levels (refer to Table E in this volume or Table E-2 in Appendix 1).
- 3) At buildings where soil-gas action levels for vapor intrusion concerns are approached or exceeded, further evaluate the need to carry out an indoor air study.

A more detailed discussion is provided below. **Site data should not be averaged over an area greater than the existing or anticipated floor space area of a building for initial evaluation of vapor intrusion hazards.** A denser area of data coverage may be required for buildings with isolated rooms directly above the slab.

The action levels are based on scientific models for vapor intrusion into buildings as well as a growing body of data from actual field investigations. A detailed discussion of the action levels is presented in Appendix 1. The use of site-specific vapor intrusion models for soil and groundwater is discouraged, especially in the absence of soil gas data. The models used are highly sensitive to parameters such as soil vapor permeability and moisture. **If site-specific models are carried out then it is imperative to include a 15cm of highly permeable fill**

material, as done for the models used to develop action levels in this guidance (e.g., “sand” in model default soil types, refer to Appendix 1, Section 2.4.1). This will help reflect likely site conditions and ensure a realistic vapor flow rate through the floor slab.

4.4.2.2 Collection and Evaluation of Soil Data

Soil data are *not* considered to be highly reliable for detailed evaluation of vapor intrusion hazards. The collection and use of soil gas data is instead preferred (refer to Section 4.4.2.4). Vapor intrusion action levels for soil should only be applied to sites where relatively minor releases of volatile contaminants have occurred and the collection of soil gas data is not considered to be necessary and/or feasible.

4.4.2.3 Collection and Evaluation of Groundwater Data

Groundwater data should be collected at all sites where significant releases of VOCs are known or thought to have occurred and compared to action levels presented in Appendix 1 of this document (Table E-1a, see also Tables F-1a and F-1b). Vapor emission rates are controlled by the concentration of VOCs in the upper few feet or even inches of the water table. Sample data should be collected from this zone, preferably by direct push, grab sample methods or monitoring wells with short (e.g., five foot) well screens. This helps to avoid mixing deeper, less contaminated groundwater with shallow groundwater. It is important to ensure that monitoring well screens span the top of the water table.

Action levels for vapor emissions from groundwater into overlying buildings are incorporated into the F-series tables in Appendix 1 and the summary tables presented at the end of this volume as well as the EAL Surfer (electronic version of the EAL lookup tables). Imported fill material or disturbed native soils should be considered to be highly permeable in site-specific assessments unless vapor flow data into existing buildings indicate otherwise. This is incorporated into the updated USEPA spreadsheets by use of a default vapor flow rate into buildings of approximately five liters per minute per 100m² of floor space (“Qsoil”).

The groundwater action levels for vapor intrusion concerns are based on an assumed three-meter depth to groundwater (see Appendix 1). These action levels may not be adequately conservative for use at sites with shallower water tables. Proceeding directly to the collection of soil gas data directly below building floors or adjacent, paved areas is instead preferable.

4.4.2.4 Collection and Evaluation of Soil Gas Data

Soil gas samples should be collected at sites where soil or groundwater data suggest potentially significant vapor intrusion concerns. Among other sources, the collection of soil gas data is discussed in the California EPA document *Soil Gas Advisory* (CalEPA 2003). Approaches to soil gas studies are also presented in the above-noted vapor intrusion guidance document prepared by the California EPA (CalEPA 2004) and the New York Department of Environmental Health (NYDEH 2006).

Soil gas samples should be collected over the core of the groundwater plume and in nearby areas of concern (e.g., near residential homes, commercial buildings, utility corridors, etc.). Ideally, samples should be collected immediately beneath the foundations of existing buildings (“subslab”). If it is impractical to collect subslab samples, then samples should be collected from paved areas immediately adjacent to buildings. In unpaved areas, soil gas samples should be collected from a depth of 1.5m (five feet) below ground surface (bgs). Samples collected from depths less than 1.5m in open (i.e., unpaved) areas are considered unreliable due to the increased potential to draw in ambient surface air (CalEPA 2004). The collection of deeper soil gas samples and soil-type data may also be useful in evaluating the lateral and vertical extent of VOCs in the subsurface, as well as in evaluation of deeper utility corridors to serve as preferential pathways for vapors into enter a building.

The collection of additional soil geotechnical data should be considered if site-specific modeling of vapor flow rates or indoor-air impacts is to be carried out, (e.g., soil grain-size analysis, moisture content, fraction organic carbon, etc.). For existing buildings with slab-on-grade construction, data must be collected from the fill material immediately beneath the slab. This is the layer of soil that controls the advective (pressure-induced) flow of vapors into the building. In most cases, the soil consists of a relatively dry, silty sand or sandy silt that exhibits a relatively high vapor permeability. This assumption is incorporated into the vapor intrusion models used to develop the action levels presented in this guidance (refer to Appendix 1). It is inappropriate to use deeper soil data to model this layer, since increased clay and moisture contents could significantly under predict the ability of the soil to convect vapors into the building. For undeveloped sites where there are no existing buildings, the presence of layer of dry, permeable fill material under future buildings should be assumed. Data can, however, be collected from deeper layers of soil and used to model these layers in the vapor intrusion model. Care should be taken to ensure that the final soil stratigraphy incorporated into the model is reflective of actual field conditions.

The use of lab-based, soil vapor permeability tests to replace the default vapor flux rate (Q_{soil}) of 5 liters/minute (per 100m² of ground floor area) used in the USEPA models is, however, discouraged. These tests often do not adequately take into account enhanced permeability due to soil heterogeneities, soil fractures, relict root structures, shallow fill material, disturbance during redevelopment, and other types of secondary permeability.

Both subslab sample data and shallow soil gas data (i.e., $\leq 1.5\text{m}$ bgs) should be compared to the soil gas action levels presented in Table C. Where action levels are approached or exceeded, the need to carry out an indoor air study should be more closely evaluated. Approaches for determining when an indoor air study should be carried out are still being developed. The California EPA vapor intrusion guidance recommends that an indoor air study be carried out if site-specific, soil-gas-to-indoor vapor intrusion models suggest that impacts to indoor air may exceed a cumulative excess cancer risk of 10^{-6} or a noncancer hazard index >1.0 (CalEPA 2004).

While this approach is generally appropriate for unrestricted land use scenarios (e.g., residential, schools, health care, day care, etc.), it may be impractical in areas of high ambient outdoor air pollution or for commercial/industrial buildings where similar chemicals are being used or stored inside of the building. For example, the concentration of benzene and other auto exhaust-related contaminants in outdoor air near roadways can exceed risk-based action levels by up to two orders of magnitude. In such cases, impacts to indoor air related to vapor intrusion from subsurface contamination can easily be masked by existing outdoor air pollution entering the building. In such cases, sampling of indoor air would not be useful. Decisions for cleanup of contaminated soil and groundwater for vapor intrusion concerns should instead be based on an evaluation of soil gas data in conjunction with ideal target indoor air goals, even if these goals cannot be currently met due to other sources of contamination, such as vehicle exhaust in ambient air. If soil gas action levels are exceeded, then cleanup of the source areas to reduce vapor intrusion concerns should be considered.

An alternative approach for determining when indoor air studies are needed at commercial/industrial (C/I) settings if soil gas action levels for commercial/industrial sites are exceeded is described below:

Step 1. Confirm and Evaluate Soil Gas Data.

- Confirm soil gas data with a second round of sampling in targeted areas of potential concern (e.g., co-located with hot spots identified in first round

of soil gas data collection and previously identified hot spots in soil and/or groundwater). If significant differences in reported concentrations of VOCs are reported at individual sample points and EALs were exceeded in one or both sampling events, consider the installation of permanent vapor monitoring wells in a denser grid (e.g., 15m to 20m grid) and additional sampling until the range of potential site conditions is adequately defined. Statistical approaches may be required at sites where wide temporal variations in concentrations of VOCs in soil gas are identified.

- If soil gas EALs for noncarcinogens are not exceeded and EALs for carcinogens are not exceeded by more than one order of magnitude (equivalent to a target risk of 10^{-5}), then no further action is warranted (refer to Table E-2 in Appendix 1).
- If soil gas EALs are exceeded by more than amounts noted above, use the USEPA soil gas spreadsheet to calculate a site-specific, cumulative excess cancer risk and noncancer hazard index (USEPA 2003, see web address in references). For example, input site-specific building and soil type data into USEPA spreadsheet for each chemical of concern and add up the calculate risks and hazard indices. Input a default vapor flux rate of 5 liters/minute per 100m² of floor space. Print out spreadsheet results for each chemical of concern; calculate cumulative risks and include in letter report with recommendations for additional actions (see Step 2). [The USEPA spreadsheet protection password is “ABC.”]

Step 2. Evaluate site-specific vapor intrusion risks.

- **Site-specific, cumulative excess cancer risk $<10^{-5}$ and/or cumulative noncancer hazard index <1.0 (and potential impacts to indoor air less than existing pollution in ambient, outdoor air).** Testing of indoor air not required. Install permanent vapor monitoring probes in areas of primary concern and test quarterly for a period of one year to confirm soil gas data. If concentrations of VOCs do not increase significantly (i.e., to exceed cumulative 10^{-5} excess cancer risk or $HI > 1.0$), no further action is warranted under current site conditions. Additional evaluation may be warranted if building conditions change or if new buildings are constructed over impacted areas.
- **Site-specific, cumulative excess cancer risk $>10^{-5}$ and/or cumulative noncancer hazard index >1.0 .** Install permanent vapor monitoring probes and resample soil gas. If resampling of soil gas indicates a

potential indoor air risk $<10^{-5}$ and/or cumulative noncancer hazard index <1.0 , carry out quarterly monitoring for one year to confirm (see above). Carry out indoor air testing if soil gas data suggest a potential excess cancer risk of $>10^{-5}$ and/or a cumulative noncancer hazard index >1.0 is confirmed (refer to Section 2.8.3).

The above approach for commercial/industrial settings is intended to be general guidance only and should not be used as a strict requirement. The appropriateness of the approach should be evaluated on a case-by-case basis. As discussed below, the collection of indoor air samples for sites with petroleum-related vapor intrusion hazards is discouraged unless reported levels of TPH and target indicator VOCs are greater than 1,000 times anticipated, ambient indoor air concentrations (see Section 4.4.4).

4.4.2.5 Soil Gas and Tight Soils

At sites where soil gas samples cannot be collected using traditional methods due to tight soil conditions (e.g., wet, clayey soils), other approaches should be attempted. In many cases, simply moving the collection probe over a few feet from the initial location will address the problem. If problems still persist, the installation of temporary soil vapor probes encased in permeable sand packs and capped with a bentonite clay mixture can be considered (refer to CalEPA 2002). The diameter and depth of the vapor probe borehole should be adjusted to allow sufficient pore space for the collection of soil gas samples. Adequate time (generally several weeks) should be allowed for VOCs in the surrounding clays to equilibrate with soil gas in the vapor probe sand pack.

Passive soil gas sampling techniques may also prove useful in tight soils, provided that the actual concentrations of VOCs present can be quantified (e.g., recent advances in “Gore™ Sorbers”). This approach has not been widely used at this time and is still being evaluated. Where possible, both “active” and passive soil gas data should be collected in amenable areas of a site and used to verify the interpretation of passive soil gas data from areas where active data could not be collected.

At sites where groundwater is impacted with VOCs and the collection of soil gas data is simply not possible, groundwater data should be compared to conservative action levels and the need to go directly to crawl space and/or indoor air sampling evaluated. At “soil only” sites, soil data should be similarly collected and compared to conservative action levels (see below).

4.4.2.6 Use of Soil Data

Soil action levels for potential vapor intrusion concerns are incorporated in the EAL lookup tables (see Appendix 1, Table A-D series and Table E-1b). At sites where minor releases of volatile chemicals have occurred (e.g., small spills around underground storage tank fill ports), direct comparison of soil action levels to site data is generally acceptable. If soil action levels are exceeded, the need to collect soil gas samples and further evaluate vapor intrusion concerns should be evaluated. **At sites where significant releases of volatile chemicals have occurred, the direct use of soil gas data in conjunction with soil data is strongly recommended.**

An advantage of the soil vapor intrusion model is the inclusion of “mass-balance” considerations in the evaluation of potential long-term impacts to indoor air. As discussed in the following section, this issue is not included in the soil gas vapor intrusion models or corresponding action levels. (Mass balance issues are also not considered in the groundwater models. The continued migration of contaminated groundwater from upgradient areas is assumed to provide an ongoing source of VOCs to areas of concern, however, and mass-balance issues are less relevant.)

4.4.2.7 Soil Gas and Mass-Balance Issues

At sites with high levels of VOCs in soil gas but a limited total mass of VOCs in soil, a mass balanced approach to the evaluation of vapor intrusion concerns may be appropriate. For example, it is not uncommon to find relatively high levels of PCE in soil gas immediately beneath the floors of dry cleaners but relatively little PCE in soil samples collected in the same area. Most of the PCE is in vapor phase, with very little total mass present. This is most likely related to the presence of dry soil with very little organic carbon directly under the floor of the building.

Based on soil gas data alone, the vapor intrusion models may predict unacceptable, long-term impacts to indoor air. The actual mass of VOCs present may be insufficient to maintain initial impacts over the full span of the exposure duration assumed in development of the action levels, however. In such cases, the action levels presented in could be overly conservative for evaluation of long-term, chronic health risk concerns and a more site-specific evaluation of vapor intrusion concerns may be warranted.

4.4.3 Collection of Indoor Air Data

In some cases, the collection of indoor data will be necessary to further evaluate vapor intrusion concerns. The collection of indoor air data without soil gas data and, if applicable, crawl space data is not recommended. Such data are critical in determining the source of any VOCs identified in indoor air. Guidance on the collection and evaluation of indoor air data is provided in the above-noted California EPA document (CalEPA 2004) and will not be repeated in detail here. Additional information is available in the Massachusetts Department of Environmental Protection document *Indoor Air Sampling and Evaluation Guide* (MADEP 2002b).

The California EPA guidance document provides a table of recommended actions at sites where impacts to indoor air are identified (CalEPA 2004). A slightly modified version of that table is provided below:

*Indoor Air Sampling Results	Response	Activities
Risk: $<10^{-6}$ HI: <0.5	No Further Action	Confirm that vapor intrusion impacts are not likely to increase in the future.
Risk: 10^{-4} to 10^{-6} HI: 0.5 to 1.0	Monitoring +/- Mitigation	Collect soil gas, indoor air and/or crawl space samples semi-annually as appropriate. Mitigation may be recommended in some cases to reduce exposure even though health risk goals may not be exceeded.
Risk: $>10^{-4}$ HI: >1.0	Mitigation Required	Institute engineering controls to mitigate exposure and collect soil gas samples and indoor air samples semiannually to verify mitigation of exposure.

*Contaminants identified in indoor air that are directly linked to the intrusion of subsurface vapors.
 Risk = Cumulative excess cancer risk
 HI = Hazard Index – Cumulative risk posed by sum of noncancer hazard quotients of specific chemicals of concern.

The original CalEPA guidance calls for monitoring +/- mitigation of indoor air impacts if the cumulative Hazard Index (HI) is between 1.0 and 3.0, with mitigation required if the HI exceeds 3.0. Acute inhalation action levels for some contaminants can be approached at HI of 3.0, however (e.g., benzene). For the purpose of this guidance, an HI of 1.0 was therefore selected as a default target for mitigation of indoor air impacts. This can be reviewed on a site-specific basis as needed.

If structures in the subject area are underlain by crawl spaces then the concurrent collection air samples from these areas should also be considered. Crawl space data should be compared directly to indoor air data. As discussed above, the dilution of VOCs in crawl spaces as air is pulled into a building is difficult to predict.

The above are initial recommendations only. Ultimate actions required at a given site should be determined on a case-by-case basis in coordination with HDOH. As noted in the California EPA guidance document, indoor air data should be used to better ascertain human health concerns when potentially significant impacts are implied by soil gas and other subsurface data. The California EPA document recommends that at least two rounds of indoor air data be collected prior to determining appropriate response activities. The scope of specific responses should be determined on a case-by-case basis in coordination with HDOH. Active mitigation of indoor air impacts may be recommended (or even required) at sites where a reduction of individual exposure is desired even though health risk objectives noted above are not exceeded. A contingency plan based on the data to be collected should be included as part of the indoor air sampling plan.

If vapor intrusion concerns are primarily for future buildings, then remediation of VOC impacts prior to construction should be considered. If this is not feasible (e.g., due to impacts from a continuing offsite source) then institutional and engineering controls to mitigate vapor intrusion concerns should be incorporated into future building designs. The scope and oversight of these controls should be determined on a site-specific basis in coordination with HDOH. Long-term oversight requirements are typically much more stringent for residential properties. In some cases, formal incorporation of engineered controls into building permits may be warranted with long-term oversight of the controls being undertaken by the planning agency.

4.4.4 Special Considerations for Petroleum-Contaminated Sites

A discussion of contaminants of potential concern for petroleum is provided in Section 2.4 (see also Figure 2.3). As noted, TPH and not benzene or other individual volatile chemicals generally drives vapor intrusion risks for releases of middle distillates and even gasolines. Vapor intrusion action levels for TPH in soil and groundwater cannot easily be calculated using the USEPA models referenced above and are not included in the EAL lookup tables. The analysis of soil gas samples for TPH is instead required (sometimes reported as *Total Volatile Hydrocarbons* or similar term). The standard used for the analyses should be similar to the product released at the site.

Testing of indoor air for petroleum-related contaminants associated with the intrusion of vapors from subsurface sources is rarely useful. Common household cleaners, glues and other products can contain petroleum and serve as indoor sources of contamination (look for “Flammable” on labels). Auto exhaust is also a major contribution to petroleum-related contaminants in outdoor air. Unless the building is located directly over heavily contaminated soil or free product on shallow groundwater, petroleum vapors related to other indoor and outdoor sources will overwhelm additional contamination related to vapors emitted from underlying soil and groundwater.

For example, ambient concentrations of benzene in urban, outdoor air related to auto-exhaust typically ranges from 1 to >5 ug/m³ (ATSDR 2007), well above the risk-based, action level for residential exposure of 0.25 ug/m³ (refer to Table C). Although less published data are available, ambient concentrations of TPH in indoor and outdoor air can exceed 1,000 ug/m³ (based on data collected at sites in Hawai‘i), well above the residential indoor air action level of 51 ug/m³. As a general rule, indoor air should only be tested if concentrations of target contaminants in soil gas exceed at least 1,000 times anticipated levels in ambient air (default soil gas:indoor air dilution factor for residences; 2,000 for commercial/industrial buildings). This correlates to concentrations of TPH in soil gas of 1,000,000 ug/m³ and 1,000 ug/m³ for benzene before it impacts to indoor air above ambient conditions might be detected.

This does not mean that the additional contamination of indoor air related to vapor intrusion is not a concern. If reported levels of TPH, BTEX or other contaminants in soil gas exceed action levels (or approved alternatives) then lower floor of the building should be inspected and cracks and gaps (e.g., around utilities) should be sealed. The building heating, air conditioning and ventilation (HVAC) system should also be inspected to ensure that it is operating properly

(e.g., maintaining a positive indoor air pressure) and that adequate fresh air is being brought into the building.

It is also important to screen for methane in soil gas samples. Additional evaluation of methane explosion hazards is required if methane levels in soil exceed 5,000 ppmv (10% of the lower explosive level; refer to Section 4.2.4). TPHgasoline vapors could also pose explosion hazards at some sites. An evaluation of potential vapor intrusion and explosion hazards will in particular be needed at sites where full cleanup of heavily contaminated soil and groundwater is not practicable and long-term monitoring or residual contamination is required.

4.5 Other Advanced EHE Approaches

4.5.1 Commercial/Industrial Land Use

Alternative vapor intrusion, gross contamination and direct exposure action levels commercial/industrial are included in Appendix 1 (Table C series, Table F series and Table I-2, respectively). These action levels are based on an assumption that only working-age adults will be present at the site on a regular basis and only during working hours. The action levels are in turn higher than those used to develop the Tier 1 EALs, based on an assumed, unrestricted, residential land use scenario. Soil action levels for leaching hazards are not affected.

An option to select commercial/industrial land use only over unrestricted (“residential”) land use is built into the updated EAL Surfer. Users are cautioned, however, to always compare site data to action levels for unrestricted land use, at least at an initial, screening level. Screening site data with only the action levels for commercial/industrial land use can place an unnecessary burden on future use of the property. If contaminants are not identified above action levels for unrestricted land use then no restrictions need to be placed on the property. Commercial/industrial action levels (or alternative, site-specific action levels) should only be referred to if the site cannot be remediated to Tier 1 EALs or acceptable, alternative action levels for unrestricted future use. Implications for land-use restriction are discussed in more detail in Section 2.7.

4.5.2 Exposed Versus Isolated Soils

As discussed in Chapter 2, the Tier 1 EALs are based on an assumption that contaminated soil is currently exposed at the ground surface or could be disturbed

and exposed at the surface in the future. This assumption eliminates the need to consider long-term management of soil at a site.

Alternative and in most cases less stringent action levels can be used to evaluate the need for remediation of isolated soils if full cleanup to the Tier 1 EALs is not feasible. For sites where unrestricted future use is desired, a depth of three meters (approximately 10 feet) is recommended to delineate between "shallow" soils, where a potential exists for disturbance of soil by future residents (e.g., excavation of swimming pools), and "isolated" soils where only periodic disturbance during construction and utility maintenance work is anticipated (CalEPA 1996). A minimum, default depth of one-meter is recommended for commercial/industrial properties to distinguish between shallow and isolated soils. Subsurface activities below this depth are likely to be closely supervised by the property owner, who will presumably be aware of contaminated soil at depth on the property and manage the soil appropriately. Landscaping and other less supervised activities could disturb and expose soils shallower than this depth.

Soil that is located under paved areas or buildings can also be considered to be isolated if appropriate, long-term management actions are implemented. This is most applicable to commercial/industrial sites where activities on the property are closely controlled. This isolation of contaminated soil under properties to be used for more sensitive purposes is generally not recommended but can be discussed with HDOH on a case-by-case basis. For example, the isolation of easily recognizable, petroleum-contaminated soil under the parking lot of a high-density residential development would be more acceptable than the isolation of soil heavily contaminated with dioxins or other persistent chemicals that are difficult to recognize in the field. Controls for long-term management of contaminated soil that is left in place at a site must be documented in a site-specific Environmental Hazard Management Plan. This is discussed in the following chapter.

Alternative soil action levels for gross contamination and direct exposure hazards are included in the lookup tables of Appendix 1 (Tables F-3 and I-3, respectively). The direct exposure action levels for deep soils are based on a construction worker exposure scenario (refer to Appendices 1 and 2). The gross hazards action levels are based on an approach developed by Massachusetts DEQ (refer to Appendix 1).

Vapor intrusion and soil leaching hazards must be evaluated for chemicals that are highly mobile before final remedial actions can be determined. Contaminants of potential concern include chlorinated solvents, chlorinated herbicides, petroleum fuels and highly soluble chemicals like perchlorate. For these chemicals, Vapor intrusion and soil leaching hazards typically take precedence over direct exposure

hazards and drive the nature of remedial actions needed, regardless of the depth of the soil below the ground surface. Refer to Section 4.2.2 and 4.2.3 for additional guidance on the evaluation of these hazards, respectively.

If contamination is present in both shallow and deep soils and full cleanup is not anticipated, then separate action levels for each zone can be established and used during the initial site investigation stage of the project. The pros and cons of remediating deep soils to action levels for unrestricted future reuse should be evaluated on a site-by-site basis. While potentially more costly in the short term, treating all soil to action levels appropriate for unrestricted use of the property can help eliminate concerns about future liability as well as increase the market value of the property.

4.5.3 Petroleum-Contaminated Soil and Groundwater

HDOH has published separate guidance for the cleanup and long-term management of petroleum-contaminated sites (HDOH 2007c; updated as discussed below). A copy of the guidance is included in Appendix 8. Petroleum contamination is widespread in many current and former industrial areas. Complete removal of contamination is not practicable in many of these areas. At a minimum, removal of vadose-zone soil contaminated above gross contamination action levels for isolated soils is recommended (e.g., 4,500 mg/kg TPH as gasolines and 5,000 mg/kg TPH as middle distillates and residual fuels for commercial/industrial sites; refer to Table F-3 in Appendix 1).

Soil gas data should be used to evaluate potential vapor intrusion hazards at sites where residual petroleum contamination exceeds action levels for unrestricted land use (refer to Section 4.4.4). Free product should be removed from groundwater to the extent practicable in order to minimize vapor intrusion and methane buildup hazards as well as reduce the potential for offsite migration concerns (e.g., via storm sewers) and reduce future impacts to groundwater. The nature and extent of remaining contamination and actions for long-term management of the site must be documented in *Environmental Hazard Management Plan* prepared for the site (refer to Chapter 5).

Note that the gross contamination action level of 4,500 mg/kg for TPHgasolines in for isolated soils represents an update to the 2,000 mg/kg action level presented in previous editions of the HDOH EALs. The gross contamination action level for TPH as middle distillates at commercial/industrial sites is set at 5,000 mg/kg base on professional judgment and experience at diesel-contaminated sites. This

exceeds the default action level 500 mg/kg for the potential presence of free product (refer to Table F-3) but is considered to be below a concentration where potentially mobile free product might be present in the soil. This issue should be evaluated on a site-by-site basis to ensure the adequacy of this action level.

4.6 Environmental Hazard Evaluations for Parklands

It is strongly recommended that sites that are to be used as parks or wildlife refuges be remediated to meet unrestricted land use when practicable. Potential hazards posed to eco-habitats should also be evaluated. Recreational-use exposure scenarios used in human health risk assessments often incorporate much lower exposure frequencies (e.g., days per year visited) and durations (total number of years) than traditional, residential exposure scenarios. This implies that substantially higher concentrations of contaminants can be left in place in a park area and not pose a threat to users of the park. Risk-based cleanup levels based on recreational land-use scenarios can even be higher (less stringent) than levels typically allowed for commercial/industrial properties.

This intuitively goes against the concept of park lands as a "refuge" for humans and wildlife. Assumption of a limited exposure frequency and duration (e.g., 100 days per year for ten years) also puts an implicit restriction on the number of days and years that an individual can visit the park incurring an unacceptably high contaminant dose. Long-term, future uses of such properties are also difficult to predict. In addition, public parks are typically frequented by children, young mothers, elderly people, and other more-sensitive subpopulations. This issue is usually omitted from standard, human health risk assessments.

Remediation of proposed parklands to unrestricted land-use standards may in some cases not technically or economically practicable. If cleanup is not feasible, and the property is intended for recreational use, then the appropriateness of allowing unrestricted access to the area should be carefully evaluated. Institutional controls may be needed, such as the imposition of access restrictions on the property or posting of signs at the property entrance that warn of potential environmental hazards.

4.7 Ecological Risk Assessment

Preparation of a more detailed Ecological Risk Assessment may be required in some cases to better evaluate and document impacts to terrestrial and aquatic habitats. An Ecological Risk Assessment is a detailed appraisal of the actual or

potential effects of a hazardous waste site on plants and animals other than people or domesticated species (USEPA 1989b). Published guidance documents for preparation of Ecological Risk Assessments include the following:

- Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments (USEPA 1997c);
- Guidance for Ecological Risk Assessments at Hazardous Waste Sites and Permitted Facilities (CalEPA 1996b); and
- Risk Assessment Guidance for Superfund: Volume II Environmental Evaluation Manual (USEPA 1989b).

Detailed guidance regarding the preparation of Ecological Risk Assessments is beyond the scope of this Manual, and the above list of references is not intended to be comprehensive. Additional Ecological Risk Assessment guidance should be referred to as needed.

5

Long-Term Management of Contaminated Sites

An expanded discussion of the long-term management of contaminated sites will be included in revisions to the Hawai'i Department of Health (HDOH) Hazard Evaluation and Emergency Response (HEER) *Technical Guidance Manual* (HDOH 2008a, anticipated Fall 2008). In the interim, refer to the HDOH guidance published for the long-term management of petroleum-contaminated sites (HDOH 2007c). Although focused on petroleum contamination, the guidance can also be expanded to other types of releases that require long-term management. A copy of the guidance is included in Appendix 8.

As discussed in petroleum guidance, an *Environmental Hazard Management Plan* should be prepared for all sites where residual contamination in soil and groundwater exceeds action levels for unrestricted land use.

A basic EHMP should include the following information (or be included in a document that contains the same information):

- Brief summary of the site background and history of contaminant releases;
- Identification of specific contaminants of concern, including TPH, “Target Indicator Compounds” and any other contaminants associated with the release (refer to Step 1);
- Clear depiction of the extent and magnitude of remaining contamination in soil, groundwater and/or soil gas, presented on easily readable, to-scale maps with a north arrow (refer to Step 2);
- Identification and discussion of all potential environmental concerns (refer to Step 3);
- Requirements for long-term monitoring of contaminants in soil, groundwater, and/or soil gas;
- Discussion of engineering and/or institutional controls needed to address identified environmental concerns, including caps, barriers, etc., needed to eliminate exposure pathways;
- Guidance on the proper management and disposal of contaminated soil and/or groundwater encountered during future site activities;

- Measures for repair or replacement of engineered controls that are disturbed or breached during future site activities; and
- Any other information required to adequately mitigate and manage remaining environmental concerns at the site.

The scope of EHMPs for individual sites will vary based on the nature and extent of the remaining contamination, as well as the potential environmental hazards posed by the contamination. A relatively short and simple discussion of proper management procedures in the final closure report may be adequate for sites where only a small amount of petroleum-contaminated soil or groundwater has been left in place and only gross contamination hazards remain. A more detailed EHMP that includes formal restrictions on site use and engineered controls to prevent exposure to residual contaminants may be required at sites where contamination is to be left in place that poses significant environmental hazards if not managed properly. A brief *Fact Sheet* that summarizes key elements of the EHMP in simple, non-technical terms may also be required for large, complex sites where significant public review is anticipated.

The use of engineered controls to prevent exposure to contaminated soil or groundwater is generally discouraged for properties that are to be developed for single-family homes or town homes where residents could dig in their yards. This is because long-term management of the controls by residents cannot be assured (e.g., maintenance of clean soil caps over contaminated soil). Permanent soil caps in commercial/industrial sites or high-density residential sites should at least 30cm (twelve inches) thick (USEPA 2003). For garden areas, at least 60cms (24 inches) of clean fill is recommended (USEPA 2003). If offsite disposal alternatives do not exist, contaminated soil could also be placed under building pads or other paved areas, provided that the location of the soil is properly surveyed and documented in the Environmental Hazard Management Plan. Utility trenches should also be backfilled with clean soil in order to reduce exposure of future workers and avoid accidental reuse of excavated soil in areas where workers and residents may be exposed to residual contaminants. Contaminated soil that is to be isolated at depth should in general be kept at least one meter above the highest groundwater level.

These are only a few of the issues that must be considered at sites where contaminated soil and groundwater are to be left in place. Refer to the HEER office Technical Guidance Manual for additional guidance.

6

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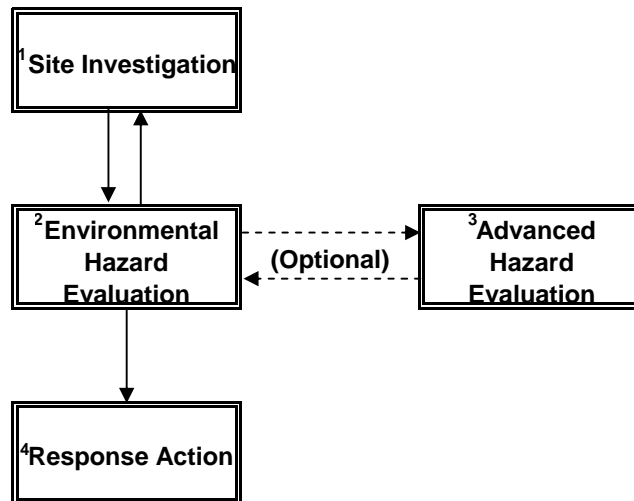
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FIGURES

Figure 1-1. Overview of the Environmental Site Assessment Process



1. The extent and magnitude of contamination above levels of potential concern is determined during the site investigation stage of the process.

2. Potential environmental concerns at contaminated sites are identified in a preliminary Environmental Hazard Evaluation (EHE). Specific, potential hazards are evaluated in more detail as needed (see below). The final EHE is used determine the need for response actions.

3. An advanced evaluation of specific environmental hazards can be carried out as needed. For example, soil gas data can be collected to better evaluate vapor intrusion hazards; soil batch tests can be carried out to better evaluate leaching hazards; a site-specific human-health risk assessment and/or ecological risk assessment can be prepared to better define risks to human and ecological receptors; etc. The conclusions are used to help support the need for response actions.

4. The most appropriate response action to address the identified environmental hazards is identified and implemented. This could include no further action, active remediation, long-term management, etc.

Figure 1-2. Summary of common environmental hazards associated with contaminated soil and groundwater.

Contaminated Soil	
Environmental Hazard	Description
Human Health Risk	
<ul style="list-style-type: none"> • Direct Exposure 	Exposure to contaminants in soil via incidental ingestion, dermal absorption and inhalation of vapors or dust in outdoor air.
<ul style="list-style-type: none"> • 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.
Impacts to Terrestrial Habitats	Toxicity to terrestrial flora and fauna
Gross contamination	Includes potentially mobile free product, odors, aesthetics, generation of explosive vapors, general resource degradation, etc.
Contaminated Groundwater	
Environmental Hazard	Description
Human Health Risk	
<ul style="list-style-type: none"> • Contamination of drinking water supplies 	Toxicity concerns related to contamination of groundwater that is a current or potential source of drinking water.
<ul style="list-style-type: none"> • Vapor Intrusion 	Emission of volatile contaminants from groundwater and intrusion into overlying buildings.
Impact to Aquatic Habitats	Discharges of contaminated groundwater and toxicity to aquatic organisms
Gross contamination	Includes taste and odor concerns for contaminated drinking water supplies, free product, potential, sheens and odors on surface water, general resource degradation, etc.

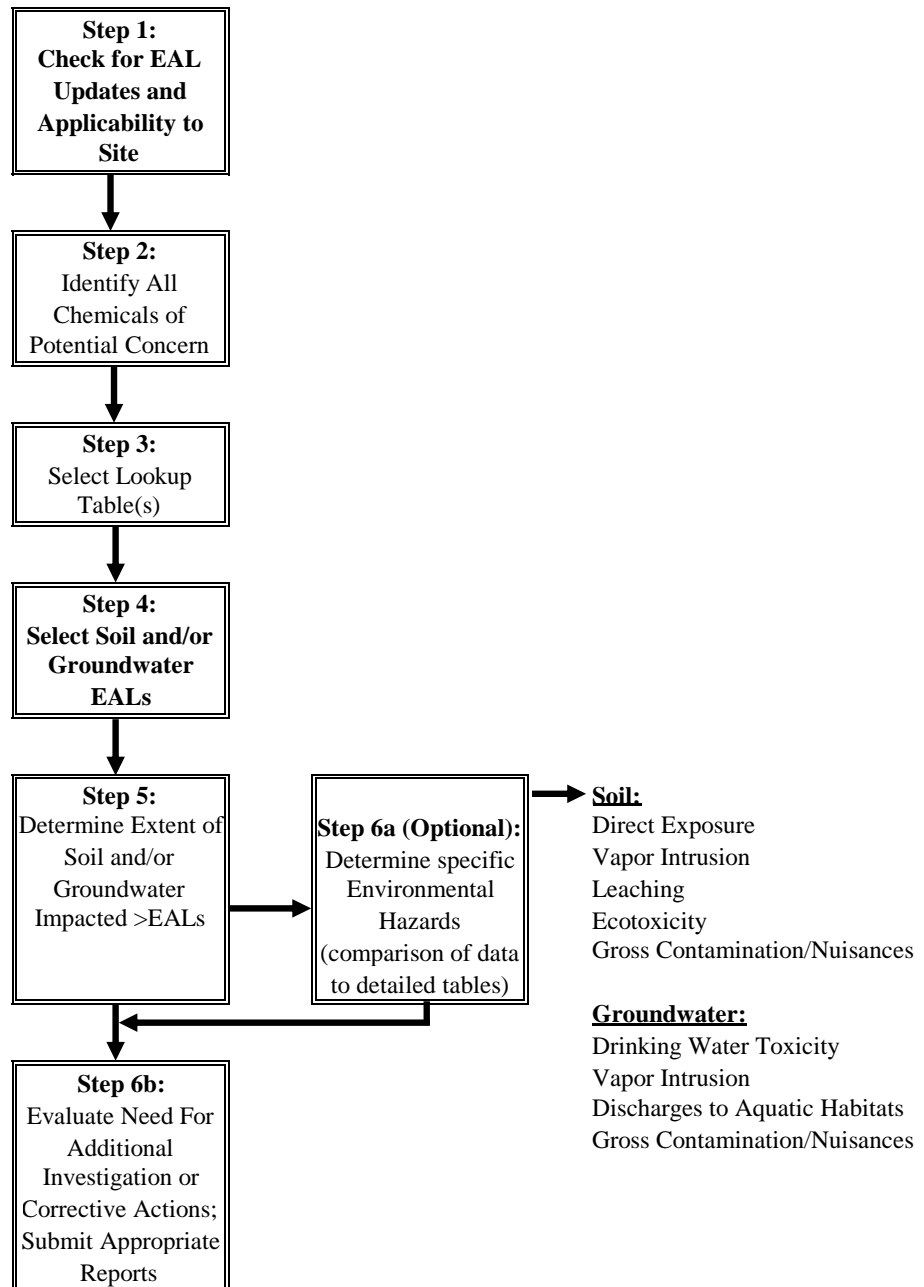


Figure 1-3. Steps for use of the Tier 1 EAL lookup tables during the site assessment process. Although not necessary for sites where cleanup to Tier 1 EALs can easily be attained, identification of specific environmental hazards is recommended and in particular required for sites where long-term, on-site management of contaminated soil and groundwater is proposed.

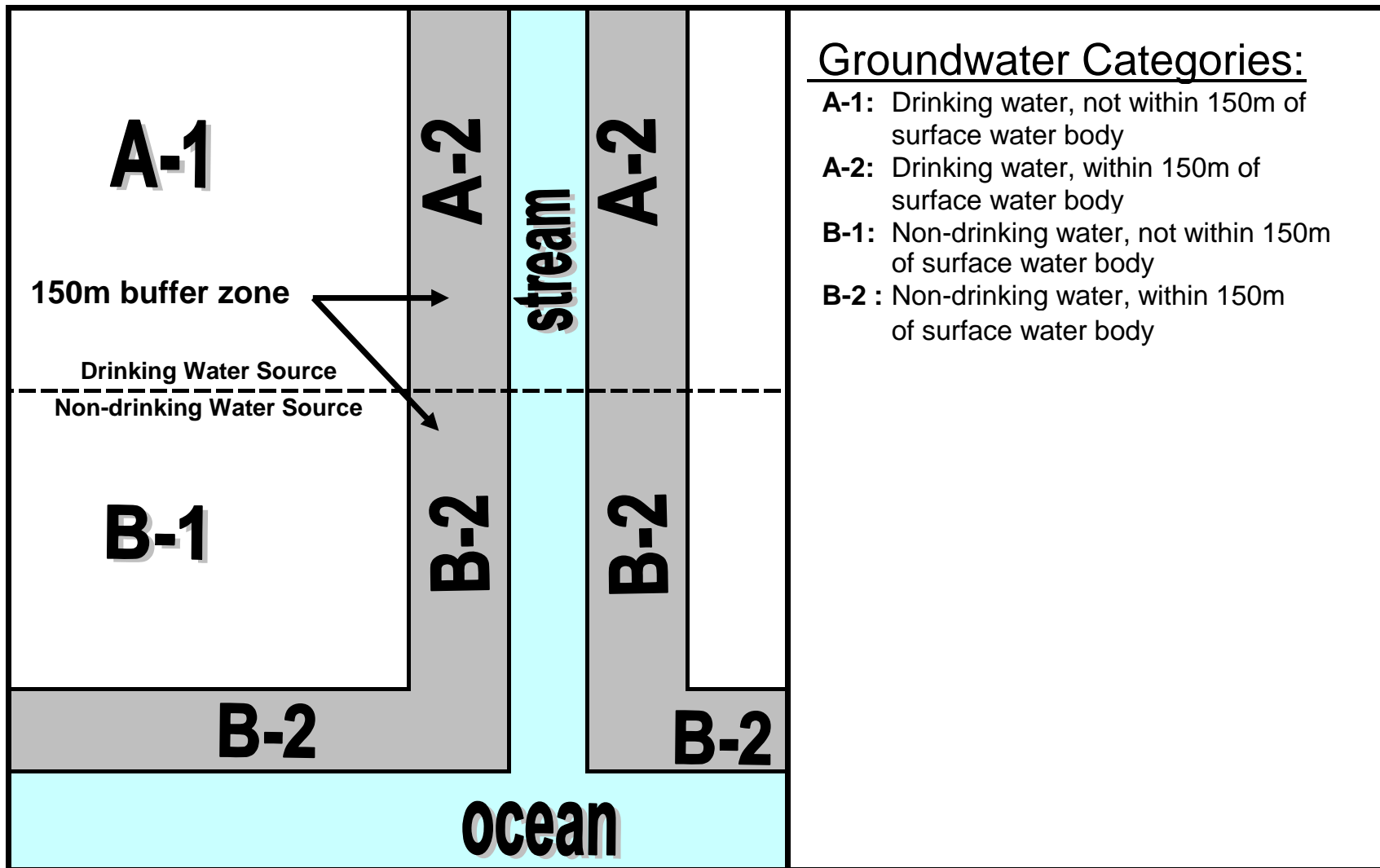


Figure 2.1. Groundwater categories used to develop the Tier 1 EAL lookup tables.

Figure 2-2. Primary references for compilation of Tier 1 Environmental Action levels.

Soil

Environmental Hazard	Primary Reference	Comments
Direct Exposure	USEPA Regional Screening Levels (RSLs)	RSLs for noncancer concerns adjusted to a Hazard Quotient of 0.2 (i.e., divided by five)
Vapor Intrusion	USEPA Vapor Intrusion Guidance and Model	Model formatted for use in tropical to temperate climates with shallow groundwater
Leaching	Massachusetts Department of Environment Soil Leaching Model	Model modified to reflect target groundwater action levels
Terrestrial Ecotoxicity	Ontario Ministry of Environment Compilation	Action levels applicable to non-sensitive, urban environments only
Gross Contamination	Massachusetts Department of Environment Gross Contamination Guidance	Generic approach for gross contamination concerns

Groundwater

Environmental Hazard	Primary Reference	Comments	
Drinking Water Toxicity	Local Agency Primary Maximum Contaminant Levels	USEPA Tapwater RSL model used for chemicals that lack Primary MCLs	
Vapor Intrusion	USEPA Vapor Intrusion Guidance and Model	Model formatted for use in tropical to temperate climates with shallow groundwater	
Discharges to Aquatic Habitats	USEPA Surface Water Standards	USEPA and other sources referred to for chemicals that lack surface water standards	
Gross Contamination	Drinking Water Resource	Local Agency Secondary Maximum Contaminant Levels	Alternative references used for chemicals that lack Secondary MCLs
	Non-Drinking Water Resource	Massachusetts Department of Environment Gross Contamination Guidance	Generic approach for gross contamination concerns

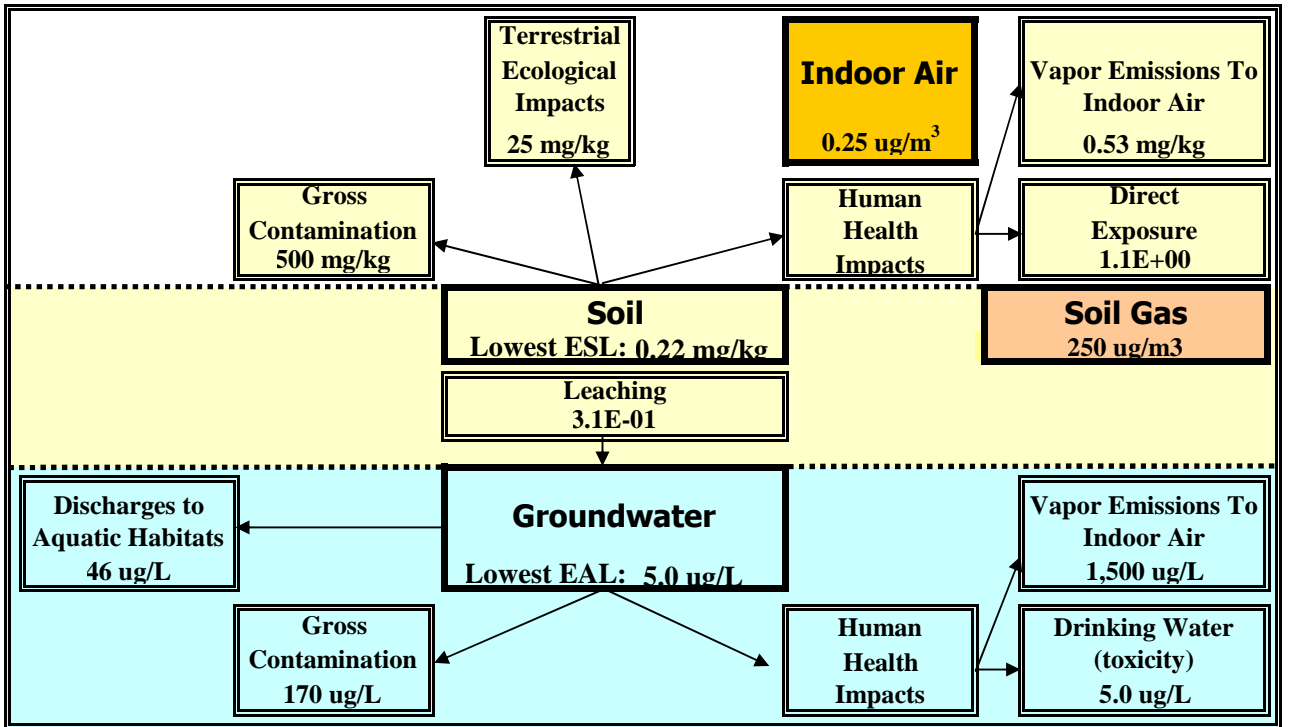


Figure 2-3. Detailed screening levels used to select final, Tier 1 soil and groundwater ESLs for benzene (assumes residential land use, exposed soils, groundwater is a source of drinking water).

Figure 2-4. Target analytes for releases of petroleum products.

Petroleum Product	Media	Recommended Target Analytes
Gasolines	Soil	TPH, benzene, toluene, ethylbenzene, xylenes (BTEX), naphthalene, MTBE and appropriate additives and breakdown products (e.g., DBA, TBA, lead, ethanol, etc.)
	Soil Gas	Same as soil plus methane
	Groundwater	Same as soil
Middle Distillates (diesel, kerosene, stoddard solvent, heating fuels, jet fuel, etc.)	Soil	TPH, BTEX, naphthalene, methylnaphthalenes (total 1- and 2-)
	Soil Gas	Same as soil plus methane
	Groundwater	Same as soil
Residual Fuels (lube oils, hydraulic oils, mineral oils, transformer oils, Fuel Oil #6/Bunker C, waste oil, etc.)	Soil	TPH, *VOCs, naphthalene, methylnaphthalenes plus remaining 15 priority pollutant PAHs, plus PCBs and heavy metals unless otherwise justified
	Soil Gas	TPH, VOCs, naphthalene, methylnaphthalenes, methane
	Groundwater	same as soil

*VOC: Volatile Organic Compounds, including BTEX and chlorinated solvent compounds

Figure 2-5. Summary of models and approaches used to develop action levels incorporated into the Tier 1 EALs (refer also to Appendix 1).

Groundwater Action Levels	
Contamination of drinking water supplies	Hawai'i DOH promulgated drinking water standards or USEPA Regional Screening Levels model for tapwater. Refer to Appendix 1 (Section 2.2 & Table D-3 series) and Appendix 2.
Vapor Intrusion	USEPA vapor intrusion spreadsheets. Refer to Appendix 1 (Section 2.4 & Table C-1a) and Appendix 4.
Impact to Aquatic Habitats	Hawai'i DOH promulgated surface water standards or USEPA and other references if not available. Refer to Appendix 1 (Section 2.3 and Table D-4 series).
Gross contamination	Massachusetts DEP approach, modified as indicated. Refer to Appendix 1 (Section 3.6 & Table G series).
Soil Action Levels	
Environmental Hazard	Reference
Direct Exposure	USEPA Regional Screening Levels models for direct exposure concerns. Refer to Appendix 1 (Section 3.2 & Table I series) and Appendix 2.
Vapor Intrusion	USEPA vapor intrusion spreadsheets. Refer to Appendix 1 (Section 3.3 & Table C-1b) and Appendix 4.
Leaching	Massachusetts DEP soil leaching model. Refer to Appendix 1 (Section 3.4 & Table E-1) and Appendix 5.
Impacts to Terrestrial Habitats	Ontario Ministry of Environment compilation of US, Canadian and Dutch terrestrial ecotoxicity screening levels. Refer to Appendix 1 (Section 3.5 & Table L) and Appendix 6.
Gross contamination	Massachusetts DEP approach, modified as indicated. Refer to Appendix 1 (Section 3.6 & Table F series).
Soil Gas and Indoor Air Action Levels	
Vapor Intrusion	USEPA vapor intrusion spreadsheets. Refer to Appendix 1 (Section 3.3 & Tables C-2 and C-3) and Appendix 4.

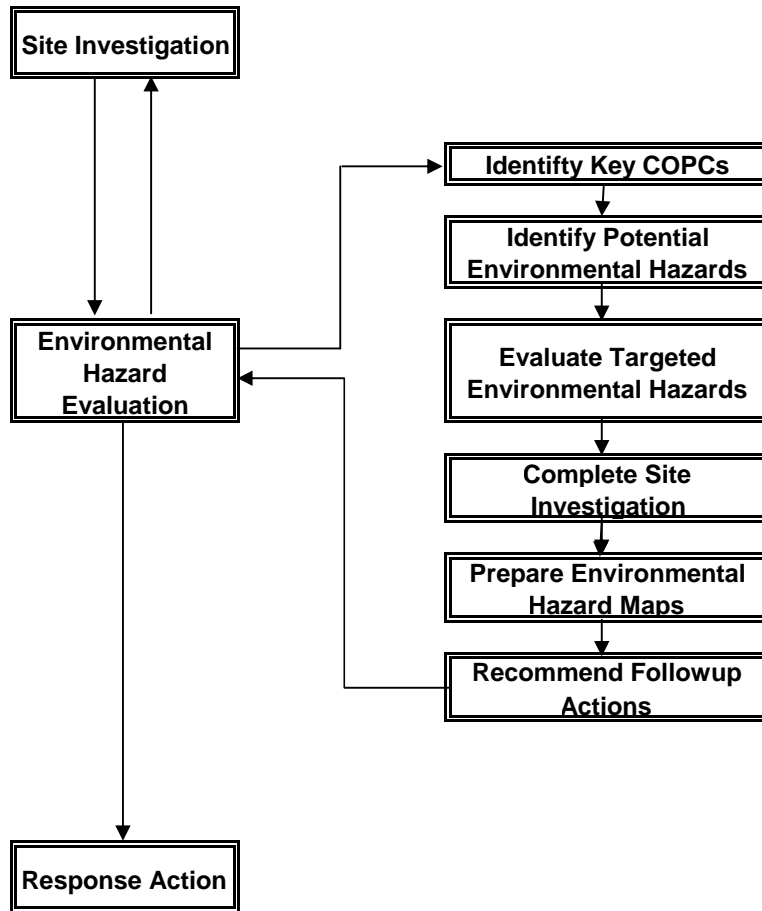


Figure 3-1. Overview of the Environmental Hazard Evaluation process (preparation of Environmental Hazard maps generally optional).

Tier 1 Environmental Action Levels Surfer

Hawai'i DOH
(Summer 2008)

Steps 1 and 2:

Click in cell and use pull-down boxes to make selection.

STEP 1: Select Site Scenario:	
² Land Use:	Unrestricted
³ Groundwater Utility:	Drinking Water Resource
⁴ Distance To Nearest Surface Water Body:	< 150m

STEP 2: Select Contaminant
BENZENE

STEP 3 (optional): Enter site data. (Potential environmental hazards highlighted in Red on Detailed EAL worksheet.)	
Soil (mg/kg):	5.1
Groundwater (ug/L):	150
Soil Gas (ug/m ³):	400

Final Tier 1 EALs	
Soil (mg/kg): 3.1E-01	X
Groundwater (ug/L): 5.0E+00	X
Soil Gas (ug/m ³): 2.5E+02	X

EALs exceeded. Refer to Detailed EALs (next tab) to identify specific environmental hazards that may be posed by contamination.

Notes

Volatile chemical. Collect soil gas data for site-specific evaluation of vapor intrusion hazards if Tier 1 action levels for this hazard exceeded (see Advanced EHE Options tab of Surfer).

Notes:

1. Site scenario options based on scenarios used to develop EAL lookup tables (HDOH 2008).
2. "Unrestricted" land use category suitable for residential housing, schools, day care, medical facilities, parks and similar sensitive uses. Use to evaluate the need for future land use restrictions. Screen using a commercial/industrial land use scenario if site is to be used only for these purposes and contamination will not be cleaned up to meet action levels (or acceptable alternatives) for unrestricted land use. Future land-use restrictions may apply (refer to Chapter 5 of Volume 1).
3. See Section 2.4 of Volume 1 for determination of groundwater utility.
4. Used to evaluate potential impacts to aquatic habitats. Chronic aquatic toxicity goals used to screen groundwater situated < 150m from an aquatic habitat. Acute aquatic toxicity goals used to screen groundwater situated >150m from an aquatic habitat. Potential for groundwater contaminated above chronic goals to migrate into the 150m buffer zone must also be evaluated.

Figure 3-2a. Printout of EAL Surfer input page, using benzene at noted concentrations in soil, groundwater and soil gas as an example.

**Tier 1 Environmental Action Levels Surfer
(Screening Levels For Specific Environmental Hazards)**

Hawai'i DOH (Summer 2008)

BENZENE

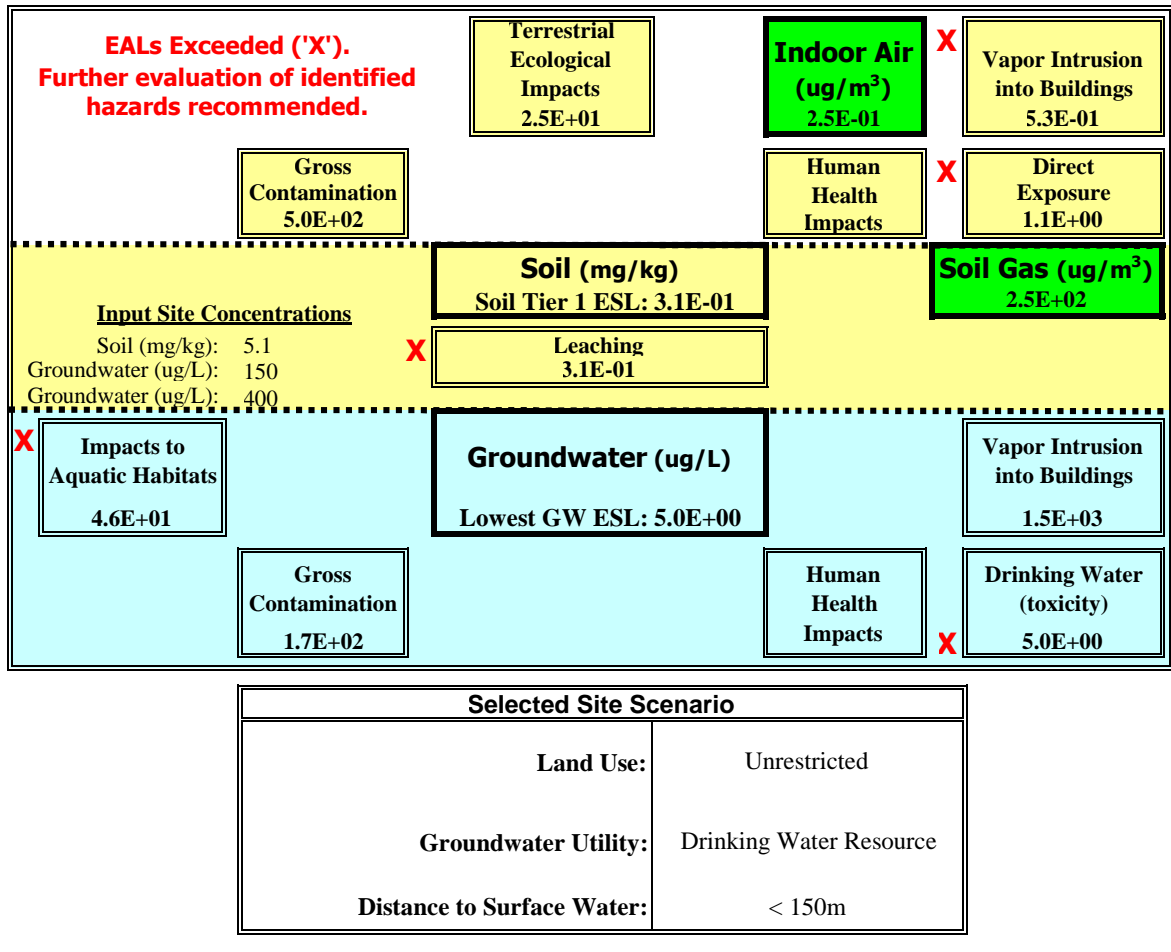


Figure 3-2b. Printout of ESL Surfer detailed environmental hazard identification page, using benzene at noted concentrations in soil and groundwater as an example.

¹Tier 1 EAL SURFER SUMMARY REPORT
Hawai'i DOH (Summer 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):	5.1
Groundwater (ug/L):	150
Soil Gas (ug/m ³):	400

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:		3.1E-01		
Basis: Leaching				

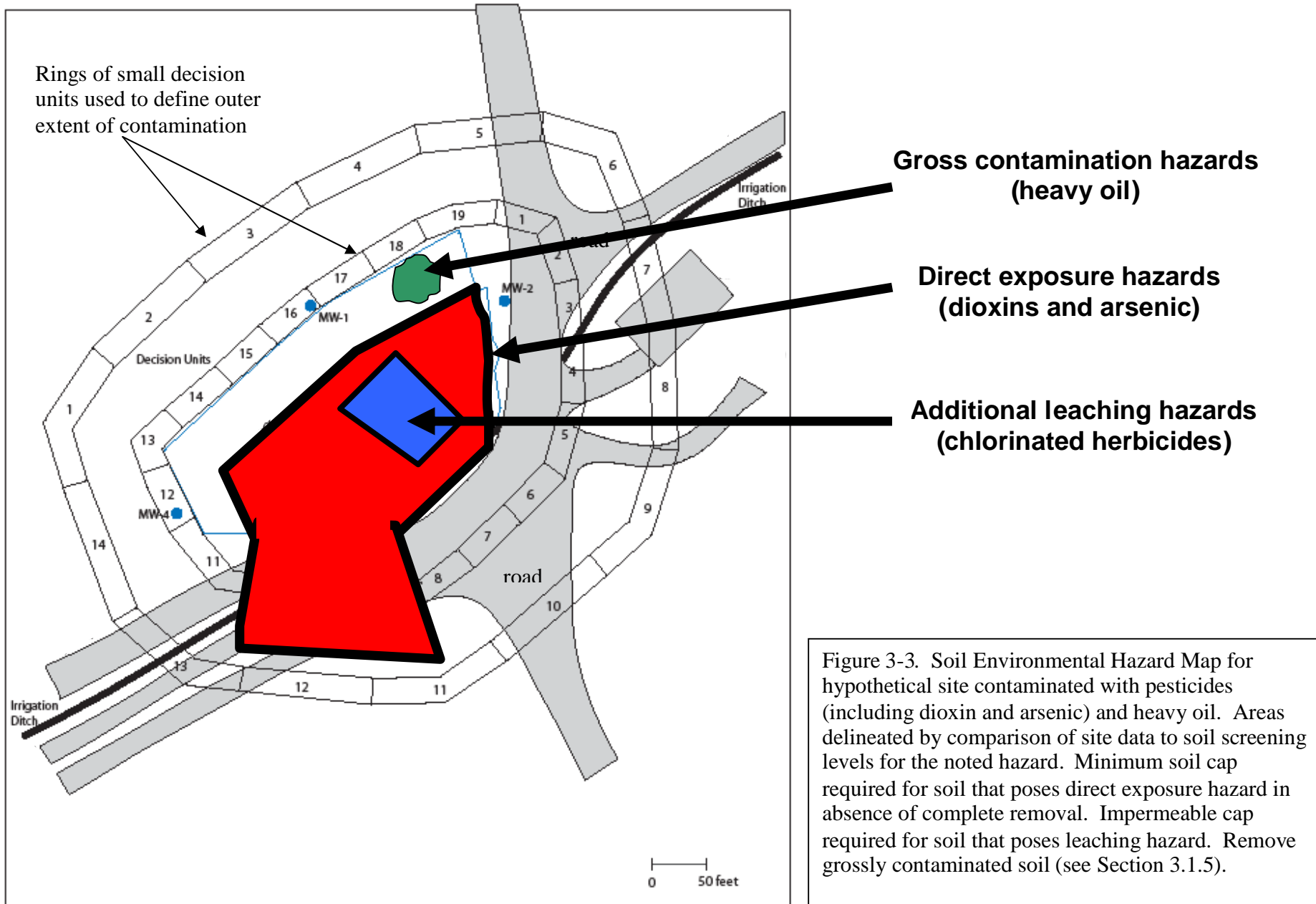
Groundwater Environmental Hazards	Units	Tier 1 Action Level	² Potential Hazard?	³ Referenced Table
Drinking Water (Toxicity):	ug/L	5.0E+00	Yes	Table D-1a
Vapor Emissions To Indoor Air:	ug/L	1.5E+03	No	Table C-1a
Aquatic Ecotoxicity:	ug/L	4.6E+01	Yes	Table D-4a
Gross Contamination:	ug/L	1.7E+02	No	Table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

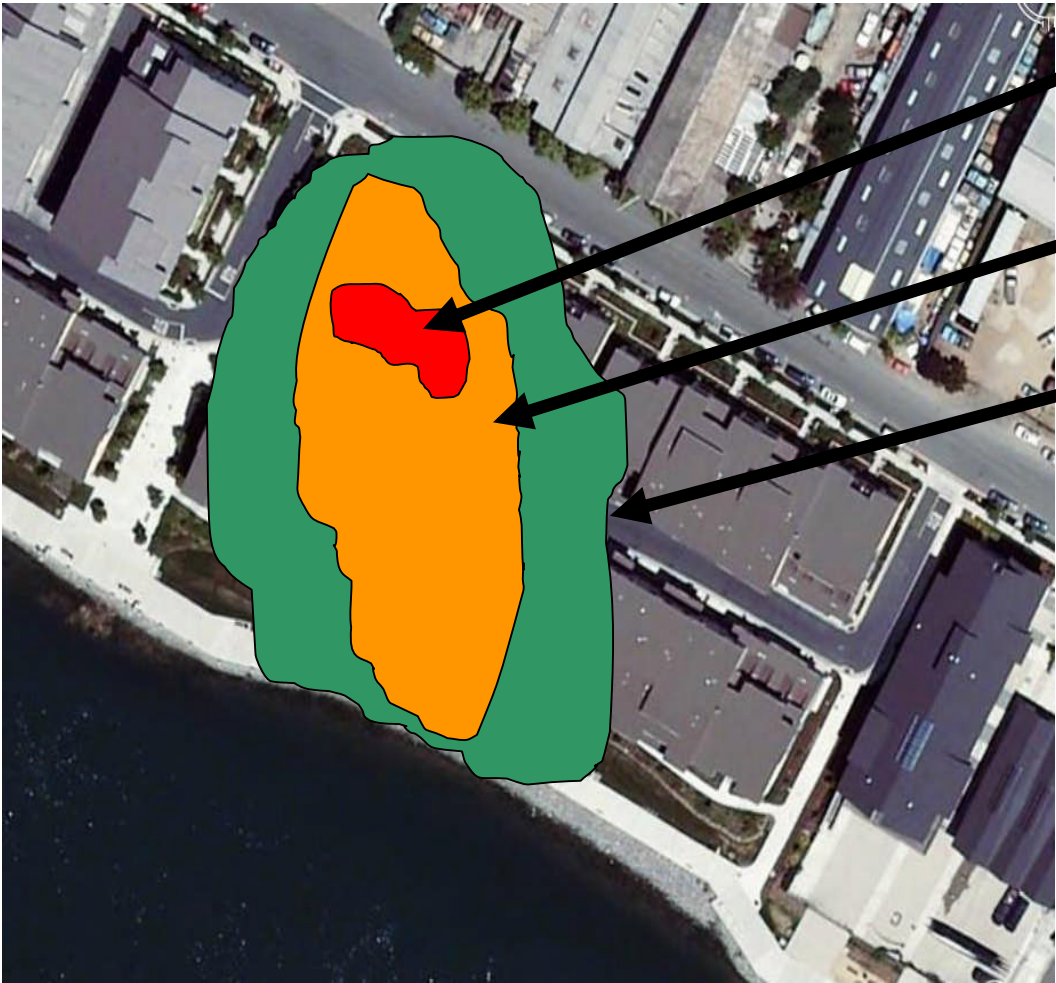
Other Tier 1 EALs:	Units	EAL	² Potential Hazard?	³ Referenced Table
Shallow Soil Gas:	ug/m ³	2.5E+02	Yes	Table C-2
Indoor Air:	ug/m ³	2.5E-01	-	Table C-3

Notes:

1. Include Surfer Summary Report in appendices of *Environmental Hazard Evaluation* (EHE) for contaminants that exceed Tier 1 EALs (refer to Chapter 3 of main text).
2. Environmental hazard could exist if concentration of contaminant exceeds action level.
3. Referenced tables presented in Appendix 1 of EHE guidance document (HDOH 2008).

Figure 3-2c. Printout of ESL Surfer summary report, using benzene at noted concentrations in soil and groundwater as an example. This page can be printed and included in the appendices of the Environmental Hazard Evaluation report. (Referenced table from Appendix 1.)





**Vapor intrusion hazards
(TPHgasoline and benzene)**

**Acute aquatic toxicity and
gross contamination hazards
(TPHgasoline, benzene,
ethylbenzene and xylenes)**

**Chronic aquatic toxicity hazards
(same contaminants)**

Figure 3-4. Groundwater Environmental Hazard Map for 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 also recommended. Long-term monitoring of remaining groundwater contamination required (see Section 3.1.5).

Key Questions		^{1,2} Common Environmental Hazards Posed by Contaminated Soil				
		Direct Exposure	Vapor Emissions to Indoor Air	Terrestrial Ecological Impacts	Gross Contamination	Leaching to Groundwater
PRE-RESPONSE	Before this response action, ³ under unrestricted use of the property, could the release have posed this environmental hazard?					
	Before this response action, ⁴ under current conditions , did the release pose this environmental hazard?					
	If the answer to the first question is YES and the second question is NO, then describe the existing conditions prior to this response action that provide controls for this hazard.					
RESPONSE ACTIONS	Describe the cleanup methods used in this response action that addressed this hazard:					
POST-RESPONSE	After this response action, ³ under unrestricted use , could the release pose this environmental hazard?					
	If the answer to the above is YES, then describe the engineering controls and institutional controls used to provide controls for this hazard:					

Figure 3.5a. Example format for summary of environmental hazards posed by contaminated soil under current and unrestricted site conditions before and after response actions.

		^{1,2} Common Environmental Hazards Posed by Contaminated Groundwater			
		Drinking Water Toxicity	Vapor Emissions to Indoor Air	Discharge to Surface Water	Gross Contamination
Key Questions					
PRE-RESPONSE	Before this response action, ³ under unrestricted use of the property, could the release have posed this environmental hazard?				
	Before this response action, ⁴ under current conditions , did the release pose this environmental hazard?				
	If the answer to the first question is YES and the second question is NO, then describe the existing conditions prior to this response action that provide controls for this hazard.				
RESPONSE ACTIONS	Describe the cleanup methods used in this response action that addressed this hazard:				
POST-RESPONSE	After this response action, ³ under unrestricted use , could the release pose this environmental hazard?				
	If the answer to the above is YES, then describe the engineering controls and institutional controls used to provide controls for this hazard:				

Figure 3.5b. Example format for summary of environmental hazards posed by contaminated groundwater under current and unrestricted site conditions before and after response actions.

Figure 3-5 notes

1. Refer to Section 1.2 and Figure 1-2 for summary of common environmental hazards posed by contaminated soil and groundwater
2. Compare representative site data for targeted contaminants to HDOH action levels (or equivalent) for the noted environmental hazard.
3. Unrestricted site conditions: Assumes an absence of current and/or future controls to prevent disturbance of contaminated soil or groundwater or the migration of contaminants into indoor air or nearby bodies of surface water (e.g., caps, vapor mitigation systems, land use restrictions, etc.).
4. Takes into account the presence of existing caps, lack of buildings threatened by vapor emissions, restrictions on land use, absence of water supply wells, monitoring data that indicate groundwater plumes are not migrating or expanding and threatening offsite wells or surface water bodies, etc.

Figure 4-1a. Example approaches to advanced evaluation of environmental hazards associated with contaminated soil.

Environmental Hazard	Example Site-Specific Evaluation Approaches
Direct Exposure	<ul style="list-style-type: none"> • Use of multi-increment sample data to evaluate direct exposure concerns in targeted decision units. • Use of Tier 2 Direct Exposure Spreadsheet to calculate alternative action levels. • Use of laboratory 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	<ul style="list-style-type: none"> • Collection of soil gas data to better evaluate vapor intrusion or explosive hazards. • Preparation of site-specific vapor intrusion model.
Leaching	<ul style="list-style-type: none"> • Collection of groundwater data. • Use of laboratory batch test model to evaluate contaminant mobility and estimate concentrations in source area leachate.
Impacts to Terrestrial Habitats	<ul style="list-style-type: none"> • Field inspection to determine the presence or absence of potentially significant, terrestrial ecological habits. • Preparation of a detailed, ecological risk assessment.
Gross Contamination	<ul style="list-style-type: none"> • Field inspection of petroleum-contaminated soil to evaluate potential gross contamination concerns (especially in existing or planned residential areas).

Figure 4-1b. Example approaches to advanced evaluation of environmental hazards associated with contaminated groundwater.

Environmental Hazard	Example Site-Specific Evaluation Approaches
Contamination of Drinking Water Resources (toxicity and/or taste & odor hazards)	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Collection of soil gas data to better evaluate vapor intrusion or explosion hazards. • Preparation of site-specific vapor intrusion model.
Impacts to Aquatic Habitats	<ul style="list-style-type: none"> • 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.
Gross Contamination	<ul style="list-style-type: none"> • Check groundwater for free product. • Check discharge areas for sheen and other gross contamination concerns.

TIER 2 DIRECT-EXPOSURE RISK ASSESSMENT MODEL

Hawai'i DOH (Summer 2008)

Calculates Tier 2 direct-exposure action levels for soil. Assumes exposure by ingestion, inhalation and dermal contact. Addresses mass-balance issues for volatile chemicals by accounting for thickness of contaminated soil (nonvolatile chemicals not affected). Does not address potential vapor intrusion concerns, nuisance concerns, leaching concerns or ecological concerns. Use default values in absence of site-specific data.

(Steps 1 through 3 - Use pull-down boxes to select options.)

Step 1. Select Contaminant: BENZENE

Step 2. Select Exposure Scenario: Residential/Sensitive Land Use

Step 3. Input Site Data:	*Tier 1 Default	Site-Specific
Thickness impacted soil (m)	infinite	1,000.0
Soil density (g/cm ³)	1.50	1.50
Particle density (g/cm ³)	2.65	2.65
Soil moisture content (ml/g)	0.10	0.10
Fraction organic carbon in soil	0.006	0.006

*Default site parameter values from USEPA Regional Screening Levels (USEPA 2008).

Step 4. *Adjust Default Exposure Assumptions (see attached worksheet)

*Generally not recommended in a Tier 2 assessment. Includes Tier 1 chemical toxicity factors.

*Tier 2 Direct Exposure Action Levels		
BENZENE		
		(mg/kg)
Residential/Sensitive Land Use	Cancer Concerns:	6.4E-01
	Noncancer Concerns:	6.5E+00
	Tier 2 Direct Exposure Action Level:	6.4E-01
**Construction/Trench Workers	Cancer Concerns:	5.9E+02
	Noncancer Concerns:	2.7E+02
	Tier 2 Direct Exposure Action Level:	2.7E+02

**Construction/Trench worker action levels take precedence over residential or commercial/industrial action levels if lower.

PROJECT NAME: _____

Guam EPA Site ID No.: _____

SPREADSHEET PREPARED BY: _____

DATE: _____

SIGNATURE: _____

COMPANY: _____

SUPPORTING SITE INVESTIGATION REPORT(S) (Note report title, date, and preparer's name and address):

Notes:

Tier 2 model based on USEPA Region IX Preliminary Remediation Goals model (October 2004) with option for mass-balance Volatilization Factor as presented in USEPA *Soil Screening Guidance* document (USEPA 1996). Refer to Tier 2 Calculations worksheet.

Figure 4-2. Primary input page of Tier2 Direct Exposure Model for site-specific calculation of soil screening levels for direct exposure to contaminants in soil. Exposure assumptions and target risks can be modified in a second worksheet as warranted. All modifications to default site characteristics and exposure assumptions must be discussed and supported in the text of the Environmental Hazard Evaluation report.

Figure 4-3a. Arsenic Tier 2 action levels, soil categories and recommended actions for sites with unrestricted (“residential”) land use.

Total Arsenic (\leq 2 mm size fraction)	Action
\leq 20 mg/kg	Within range of natural background. No further action required and no restrictions on land use.
$>$ 20 mg/kg	Exceeds typical background. Re-evaluate local background data as available. Test soil for bioaccessible arsenic if background is potentially exceeded.
Bioaccessible Arsenic (\leq250μm size fraction)	Action
R-1 Soils (\leq 4.2 mg/kg)	No further action required and no restrictions on land use.
R-2 Soils ($>$ 4.2 but \leq 23 mg/kg)	<p>Within USEPA range of acceptable health risk. Consider removal and offsite disposal of localized spill areas when possible in order to reduce potential exposure (not required for large, former field areas). Use of soil as interim (long-term) cover at a regulated landfill may also be possible.</p> <p>For existing homes, consider measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.). For new developments on large, former field areas, notify future homeowners of elevated levels of arsenic on the property (e.g., include in information provided to potential buyers during property transactions).</p>

Figure 4-3a (cont.). Arsenic Tier 2 action levels, soil categories and recommended actions for sites with unrestricted (“residential”) land use.

<p>R-3 Soils (>23 mg/kg)</p>	<p>For existing homes, removal or onsite isolation of exposed soil is strongly recommended. Consider a minimum 30cm (one foot) cover of clean fill material (60cm or two feet in potential garden areas) if soil cannot be removed. An easily identifiable marker barrier should be placed between the contaminated soil and the overlying fill (e.g., orange construction fencing or geotextile/geonet material). In the interim, take measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.). Children should avoid areas of bare soil and regular work in gardens areas.</p> <p>For new residential developments, removal and offsite disposal of soil should be strongly considered. At a minimum, consider removal and offsite disposal of soil with concentrations of bioaccessible arsenic that approach or exceed 180 mg/kg (direct exposure action level for construction and trench workers). Use of soil as daily cover at a regulated landfill may be possible if concentrations of bioaccessible arsenic meet C-2 commercial/industrial soil criteria.</p> <p>If offsite disposal is not feasible but redevelopment of the property is still desired, consider use of soil as structural fill under public buildings, parking lots, private roads, or other paved and well-controlled structures. If capping in open areas is unavoidable, consider a 30cm (one foot) minimum cap thickness with an easily definable marker barrier placed between the soil and the overlying clean fill (e.g., orange construction fencing or geotextile fabric). Capping of R-3 soils on newly developed, private lots is not recommended due to difficulties in ensuring long-term management of the soil. Backfill utility corridors with clean fill material (e.g., R-1 soils) to avoid excavation and inappropriate reuse of the soil in the future.</p> <p>Require formal, long-term institutional controls to ensure appropriate management of soil in the future (e.g., Covenants, Conditions and Restrictions (CC&Rs), deed covenants, risk management plans, etc.). All areas of capped soil should be delineated on a surveyed map of the property to be subsequently included in the risk management plan.</p>
-------------------------------------	---

Figure 4-3b. Tier Arsenic Tier 2 action levels, soil categories and recommended actions at sites restricted to commercial/industrial land use only.

Total Arsenic (\leq 2 mm size fraction)	Action
\leq 20 mg/kg	Within range of natural background. No further action required and no restrictions on land use.
$>$ 20 mg/kg	Exceeds typical background. Re-evaluate local background data as available. Test soil for bioaccessible arsenic if background is potentially exceeded.
Bioaccessible Arsenic (\leq250μm size fraction)	Action
C-1 Soils ($>$4.2 mg/kg but \leq19 mg/kg)	<p>No remedial action required. However, consider remediation of commercial/industrial properties to meet Residential R-1 (preferred) or R-2 action levels when feasible in order to minimize restrictions on future land use. Note that this may require a more detailed sampling strategy than typically needed for commercial/industrial properties (e.g., smaller decision units).</p> <p>Require formal, long-term institutional controls to restrict use of property to commercial/industrial purposes if the site will not be investigated to the level of detail required for future, unrestricted land use (i.e., inform potential buyers, deed covenants, risk management plans, etc.).</p>
C-2 Soils ($>$19 but \leq95 mg/kg)	<p>Within USEPA range of acceptable health risk. Remedial actions vary depending on site-specific factors, including current and planned use, available options for onsite isolation or offsite disposal, and technical and economical constraints (see text). Potential actions include:</p> <p>Consider removal and offsite disposal of small, easily identifiable “hot spots” when possible in order to reduce the average concentration of bioaccessible arsenic on the property. Use of C-2 soils as daily cover (short-term) at a regulated landfill may also be possible.</p> <p>For sites that have already been developed, consider a minimum 30cm (one foot) cover of clean fill material if the soil cannot be removed (15cm or six inches minimum interim fill). If capping of soil is not feasible, consider measures to reduce daily exposure to soil (e.g., maintain lawns, ensure good hygiene, etc.).</p> <p>For new developments, consider isolation of soil under buildings, private roads or other permanent structures if technically and economically feasible. If isolation under permanent structures is not feasible, consider a minimum 30cm (one foot) cover of clean fill material. Maintain landscaping and lawns in open areas where soil will not be capped. Backfill utility corridors with clean fill material (e.g., R-1 soils) to avoid excavation and inappropriate reuse of contaminated soil in the future.</p> <p>Require formal, long-term institutional controls to restrict use of site to commercial/industrial purposes only and ensure appropriate management of soil if exposed in the future (e.g., inform potential buyers, deed covenants, risk</p>

Figure 4-3b (cont). Arsenic Tier 2 action levels, soil categories and recommended actions at sites restricted to commercial/industrial land use only.

	<p>management plans, etc.). All areas of capped soil should be delineated on a surveyed map of the property to be subsequently included in the risk management plan.</p>
<p>C-3 Soils (>95 mg/kg)</p>	<p>Removal of soil at existing commercial/industrial sites strongly recommended. At a minimum, consider removal and offsite disposal of soil with concentrations of bioaccessible arsenic that approach or exceed 180 mg/kg (direct exposure action level for construction and trench workers). If C-3 soils cannot be removed for technical or economic reasons, consider a minimum 30 cm (one-foot) cover of clean fill material (60 cm or two feet in potential deep landscaping areas) and placement of an easily identifiable marker barrier between the clean fill and the underlying soil (e.g., orange construction fencing or geotextile/geonet material).</p> <p>For new developments, removal and offsite disposal of soil should be strongly considered. At a minimum, consider removal and offsite disposal of soil with concentrations of bioaccessible arsenic that approach or exceed 180 mg/kg (direct exposure action level for construction and trench workers).</p> <p>If offsite disposal is not feasible but redevelopment of the property is still desired, consider use of soil as structural fill under public buildings, private roads, or other paved and well-controlled structures. If capping in open areas is unavoidable, consider a one-foot minimum cap thickness with an easily definable marker barrier placed between the soil and the overlying clean fill (e.g., orange construction fencing or geotextile/geonet material). Backfill utility corridors with clean fill material (e.g., R-1 soils) to avoid excavation and inappropriate reuse of contaminated soil in the future.</p> <p>Require formal, long-term institutional controls to ensure appropriate management of soil in the future (e.g., inform potential buyers, deed covenants, risk management plans, etc.). All areas of capped soil should be delineated on a surveyed map of the property to be subsequently included in the risk management plan.</p>

Figure 4-4a. TEQ dioxins Tier 2 action levels, soil categories and recommended actions for sites with unrestricted (“residential”) land use.

Dioxins (TEQ)	Action
R-1 ≤42 ng/kg	No further action required.
R-2 >42 but ≤450 ng/kg	<p>Within USEPA range of acceptable health risk. Consider removal and offsite disposal of localized spill areas when possible in order to reduce potential exposure (not required for large, former field areas). Use of soil as interim (long-term) cover at a regulated landfill may also be possible.</p> <p>For existing homes, consider measures to reduce daily exposure to soil (e.g., maintain lawn cover, ensure good hygiene, thoroughly wash homegrown produce, etc.). For new developments on large, former field areas, notify future homeowners of elevated levels of dioxin on the property (e.g., include in information provided to potential buyers during property transactions).</p>
R-3 >450 ng/kg	Residential use not recommended in absence of remedial actions to reduce potential exposure. Refer to actions recommended for dioxin contaminated soils that fall within the R-3 residential soil category (Figure 4-3a).

*Updated to reflect dioxin slope factors in September 2008 USEPA RSLs (USEPA 2008a).

Figure 4-4b. TEQ dioxins Tier 2 action levels, soil categories and recommended actions at sites restricted to commercial/industrial land use only.

Dioxins (TEQ)	Action
C-1 ≤170 ng/kg	No further action required.
C-2 >170 but ≤1,800 ng/kg	<p>Within USEPA range of acceptable health risk. Remedial actions vary depending on site-specific factors, including current and planned use, available options for onsite isolation or offsite disposal, and technical and economical constraints. Refer to actions recommended for dioxin contaminated soils that fall within the C-2 commercial/industrial soil category (Figure 4-3b).</p> <p>Disposal of soil in a regulated landfill or use as daily fill may be limited by the Federal ban on soil with >1,000 ng/kg TEQ dioxins from landfills.</p>
C-3 >1,800 ng/kg	Commercial/industrial use not recommended in absence of remedial actions to reduce potential exposure. Refer to actions recommended for dioxin contaminated soils that fall within the C-3 commercial/industrial soil category (Figure 4-3b).

*Updated to reflect dioxin slope factors September 2008 USEPA RSLs (USEPA 2008a).

Figure 4-5. Technical Chlordane Tier 2 action levels for soil (assumes no other contaminants are present above Tier 1 or Tier 2 EALs).

Land Use	Direct Exposure (mg/kg)	¹Leaching (mg/kg)	²Final Tier 2 Action level (mg/kg)
Unrestricted (“residential”)	16	29	16
Commercial/Industrial Only	65	29	29

1. Appendix 1. See additional guidance for evaluation of soil leaching hazards in Chapter 4.
2. Lowest of direct-exposure and leaching soil action level

Batch Test Leaching Model
Version: Summer 2008
Hawai'i Department of Health

STEPS:

1. Select chemical from pulldown list (unlisted chemicals - unprotect spreadsheet and input chemical name and chemical constants).
2. Input total contaminant concentration and SPLP (or other applicable batch test) concentration.
3. Input sample properties. Use default values if sample-specific data are not available.
4. Input Batch Test method information. Default SPLP method parameter values noted.
5. Input groundwater:leachate dilution factor (DF of 1.0 = no dilution; USEPA default = 20, USEPA 2002).
6. Input target groundwater action level for comparison to model calculation of groundwater impacts (optional).
7. Spreadsheet calculates sample-specific Kd value and dissolved-phase concentration of contaminant in saturated sample.
8. Spreadsheet calculates concentration of contaminant in groundwater following impact by leachate.

Step 1: Select Contaminant (use pulldown list)		PERCHLORATE	
Step 2: Input Sample Data		DEFAULT	INPUT
¹ Concentration in soil sample (mg/kg)		N/A	9.2E+00
¹ Concentration in Batch Test solution (ug/L)		N/A	3.7E+02
Step 3: Input Sample Properties (⁵USEPA soil defaults noted)			
Sample density (g/cm ³)		1.50	1.50
Particle density (g/cm ³)		2.65	2.65
Fraction air-filled porosity (assume saturated soil)		0.00	0.00
Step 4: Batch Test Method Data (SPLP defaults noted)			
² Batch Test Solution Volume (ml):		2,000	2,000
² Batch Test Solution Density (g/cm ³):		1.0	1.0
² Batch Test Sample Weight (grams)		100	100
Step 5: Input Groundwater/Leachate Dilution Factor		DEFAULT	INPUT
		20	20
Step 6 (optional): Input Target Groundwater Concentration (ug/L)			6.0E+00
Model Results			
³ Kd partition Coefficient (cm ³ /g):			4.9E+00
⁶ Estimated Concentration in Source Area Leachate (ug/L):			1.8E+03
⁷ Estimated Concentration in Groundwater (ug/L):			8.9E+01

X: Target groundwater action level potentially exceeded.

Chemical Constants (selected from Constants worksheet)	
Kh (atm m3/mole)	0.00E+00
Kh (dimensionless)	0.00E+00
Solubility (ug/L)	2.00E+08

Kd < 20. Contaminant potentially mobile in leachate for concentration and soil type tested. Soil leaching and groundwater impact concerns must be further addressed if target groundwater action level is exceeded.

Calculations:	
Sample porosity - total	0.43
Sample porosity - air-filled	0.00
Sample porosity - water-filled	0.43
Batch Test Solution Mass (grams)	2.0E+03
Batch Test Sample Mass (grams)	1.0E+02
Sample Mass:Solution Mass Ratio (gm/gm)	5.0E-02
Total Mass of Contaminant (ug)	9.2E+02
Mass Contaminant in Batch Test Solution (ug)	7.4E+02
Mass Contaminant Sorbed to Soil (ug)	1.8E+02
Concentration Sorbed (ug/kg)	1.8E+03
Batch Test Percent Solid Phase	19.6%
Batch Test Percent Dissolved Phase	80.4%
Batch Test Solid-Phase Contaminant Conc. (mg/kg)	1.8E+00
Batch Test Solution Contaminant Conc. (ug/L)	3.7E+02

Figure 4-6. Input page of Batch Leaching Test model for laboratory-based evaluation of leaching of contaminants from soil.

TABLES

**TABLE A: GROUNDWATER IS A CURRENT OR
POTENTIAL SOURCE OF DRINKING
WATER**

**TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water**

CONTAMINANT	>150m to Surface Water Body		≤150m to Surface Water Body	
	¹ Soil (mg/kg)	² Groundwater (ug/L)	¹ Soil (mg/kg)	² Groundwater (ug/L)
ACENAPHTHENE	2.0E+01	2.0E+01	2.0E+01	2.0E+01
ACENAPHTHYLENE	1.0E+02	2.4E+02	1.3E+01	3.0E+01
ACETONE	8.6E-01	1.5E+03	8.6E-01	1.5E+03
ALDRIN	2.9E-02	4.0E-03	2.9E-02	4.0E-03
AMETRYN	1.1E+01	1.5E+02	1.1E+00	1.5E+01
AMINO,2- DINITROTOLUENE,4,6-	1.2E+00	7.3E+01	2.5E-01	1.5E+01
AMINO,4- DINITROTOLUENE,2,6-	1.2E+00	7.3E+01	2.5E-01	1.5E+01
ANTHRACENE	2.5E+00	7.3E-01	2.5E+00	7.3E-01
ANTIMONY	6.3E+00	6.0E+00	6.3E+00	6.0E+00
ARSENIC	2.0E+01	1.0E+01	2.0E+01	1.0E+01
ATRAZINE	1.1E-01	3.0E+00	1.1E-01	3.0E+00
BARIUM	7.5E+02	2.0E+03	7.5E+02	2.0E+03
BENZENE	3.1E-01	5.0E+00	3.1E-01	5.0E+00
BENZO(a)ANTHRACENE	1.5E+00	2.7E-02	1.5E+00	2.7E-02
BENZO(a)PYRENE	1.5E-01	1.4E-02	1.5E-01	1.4E-02
BENZO(b)FLUORANTHENE	1.5E+00	9.2E-02	1.5E+00	9.2E-02
BENZO(g,h,i)PERYLENE	2.7E+01	1.0E-01	2.7E+01	1.0E-01
BENZO(k)FLUORANTHENE	1.5E+01	4.0E-01	1.5E+01	4.0E-01
BERYLLIUM	4.0E+00	4.0E+00	4.0E+00	2.7E+00
BIPHENYL, 1,1-	5.2E-01	5.0E-01	5.2E-01	5.0E-01
BIS(2-CHLOROETHYL)ETHER	3.1E-05	1.2E-02	3.1E-05	1.2E-02
BIS(2-CHLOROISOPROPYL)ETHER	3.5E-03	3.2E-01	3.5E-03	3.2E-01
BIS(2-ETHYLHEXYL)PHTHALATE	3.5E+01	6.0E+00	3.5E+01	6.0E+00
BORON	1.0E+02	4.1E+01	1.0E+02	4.1E+01
BROMODICHLOROMETHANE	4.2E-03	2.2E-01	4.2E-03	2.2E-01
BROMOFORM	9.1E-01	1.0E+02	9.1E-01	1.0E+02
BROMOMETHANE	1.8E-01	8.7E+00	1.8E-01	8.7E+00
CADMIUM	1.2E+01	3.0E+00	1.2E+01	3.0E+00
CARBON TETRACHLORIDE	2.7E-02	5.0E+00	2.7E-02	5.0E+00
CHLORDANE (TECHNICAL)	1.6E+01	9.0E-02	1.6E+01	4.0E-03
CHLOROANILINE, p-	1.5E-02	1.2E+00	1.5E-02	1.2E+00
CHLOROBENZENE	1.8E+00	5.0E+01	1.6E+00	2.5E+01
CHLOROETHANE	2.8E-01	3.9E+00	1.2E+00	1.6E+01
CHLOROFORM	1.8E-02	7.0E+01	1.8E-02	7.0E+01
CHLOROMETHANE	1.0E-01	1.8E+00	1.0E-01	1.8E+00
CHLOROPHENOL, 2-	1.3E-02	1.8E-01	1.3E-02	1.8E-01
CHROMIUM (Total)	5.0E+02	1.0E+02	5.0E+02	7.4E+01
CHROMIUM III	7.5E+02	5.7E+02	7.5E+02	7.4E+01
CHROMIUM VI	8.0E+00	2.1E-01	8.0E+00	2.1E-01
CHRYSENE	1.4E+01	3.5E-01	1.4E+01	3.5E-01
COBALT	4.0E+01	4.2E-02	4.0E+01	4.2E-02
COPPER	2.3E+02	2.9E+00	2.3E+02	2.9E+00
CYANIDE (Free)	1.0E+02	1.0E+00	1.0E+02	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	2.0E-02	6.1E-01	2.0E-02	6.1E-01
DALAPON	9.1E-02	2.0E+02	9.1E-02	2.0E+02
DIBENZO(a,h)ANTHRACENE	1.5E-01	9.2E-03	1.5E-01	9.2E-03
DIBROMO,1,2- CHLOROPROPANE,3-	9.0E-04	4.0E-02	9.0E-04	4.0E-02
DIBROMOCHLOROMETHANE	1.7E-03	1.6E-01	1.7E-03	1.6E-01
DIBROMOETHANE, 1,2-	7.4E-05	6.5E-03	7.4E-05	6.5E-03
DICHLOROBENZENE, 1,2-	8.5E-01	1.0E+01	8.5E-01	1.0E+01
DICHLOROBENZENE, 1,3-	2.1E+01	1.8E+02	7.4E+00	6.5E+01
DICHLOROBENZENE, 1,4-	3.7E-02	5.0E+00	3.7E-02	5.0E+00
DICHLOROBENZIDINE, 3,3-	1.9E-01	1.5E-01	1.9E-01	1.5E-01
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.0E+00	2.8E-01	2.0E+00	1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.4E+00	2.0E-01	1.4E+00	1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.7E+00	1.3E-02	1.7E+00	1.0E-03
DICHLOROETHANE, 1,1-	9.8E-02	2.4E+00	9.8E-02	2.4E+00
DICHLOROETHANE, 1,2-	2.2E-03	1.5E-01	2.2E-03	1.5E-01
DICHLOROETHYLENE, 1,1-	1.2E+00	7.0E+00	1.2E+00	7.0E+00

**TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water**

CONTAMINANT	>150m to Surface Water Body		≤150m to Surface Water Body	
	¹ Soil (ug/L)	² Groundwater (ug/L)	¹ Soil (mg/kg)	² Groundwater (ug/L)
DICHLOROETHYLENE, Cis 1,2-	1.2E+00	7.0E+01	1.2E+00	7.0E+01
DICHLOROETHYLENE, Trans 1,2-	2.1E+00	1.0E+02	2.1E+00	1.0E+02
DICHLOROPHENOL, 2,4-	3.6E-02	3.0E-01	3.6E-02	3.0E-01
DICHLOROPHENOXYACETIC ACID (2,4-D)	3.4E-01	7.0E+01	2.0E-01	4.0E+01
DICHLOROPROPANE, 1,2-	4.1E-02	5.0E+00	4.1E-02	5.0E+00
DICHLOROPROPENE, 1,3-	1.6E-02	4.3E-01	1.6E-02	4.3E-01
DIELDRIN	7.4E-03	4.2E-03	3.3E-03	1.9E-03
DIETHYLPHTHALATE	2.0E+01	9.4E+02	3.1E-02	1.5E+00
DIMETHYLPHENOL, 2,4-	1.4E+01	1.2E+02	1.3E+01	1.1E+02
DIMETHYLPHTHALATE	2.2E+01	9.4E+02	3.5E-02	1.5E+00
DINITROBENZENE, 1,3-	1.3E-01	3.7E+00	1.3E-01	3.7E+00
DINITROPHENOL, 2,4-	4.4E+00	7.3E+01	4.4E+00	7.3E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	4.4E+00	7.3E+01	2.7E+00	4.4E+01
DINITROTOLUENE, 2,6- (2,6-DNT)	2.3E+00	3.7E+01	2.3E+00	3.7E+01
DIOXANE, 1,4-	1.2E-03	6.1E+00	1.2E-03	6.1E+00
DIOXINS (TEQ)	4.5E-06	3.0E-05	4.5E-06	5.0E-06
DIURON	1.6E+00	7.3E+01	1.4E+00	6.0E+01
ENDOSULFAN	1.2E-01	3.4E-02	3.2E-02	8.7E-03
ENDRIN	6.0E-02	3.7E-02	4.0E-03	2.3E-03
ETHANOL	4.5E+00	5.0E+04	4.5E+00	5.0E+04
ETHYLBENZENE	1.6E+00	3.0E+01	1.6E+00	3.0E+01
FLUORANTHENE	4.0E+01	4.0E+01	4.0E+01	8.0E+00
FLUORENE	1.3E+02	2.4E+02	7.3E+00	3.9E+00
GLYPHOSATE	1.9E+00	6.0E+02	2.0E-01	6.5E+01
HEPTACHLOR	1.1E-01	5.3E-02	1.1E-01	3.6E-03
HEPTACHLOR EPOXIDE	4.6E-02	5.3E-02	3.1E-03	3.6E-03
HEXACHLORO BENZENE	3.0E-01	1.0E+00	3.0E-01	1.0E+00
HEXACHLORO BUTADIENE	2.0E-01	8.6E-01	2.0E-01	8.6E-01
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	9.0E-02	1.6E-01	4.5E-02	8.0E-02
HEXACHLOROETHANE	3.0E-01	4.8E+00	3.0E-01	4.8E+00
HEXAZINONE	1.2E+02	1.2E+03	1.2E+02	1.2E+03
INDENO(1,2,3-cd)PYRENE	1.5E+00	9.2E-02	1.5E+00	9.2E-02
ISOPHORONE	6.9E-01	7.1E+01	6.9E-01	7.1E+01
LEAD	2.0E+02	1.5E+01	2.0E+02	5.6E+00
MERCURY	4.7E+00	2.0E+00	4.7E+00	2.5E-02
METHOXYCHLOR	2.6E+01	3.0E-02	2.6E+01	3.0E-02
METHYL ETHYL KETONE	6.9E+00	7.1E+03	6.9E+00	7.1E+03
METHYL ISOBUTYL KETONE	4.5E-01	1.7E+02	4.5E-01	1.7E+02
METHYL MERCURY	1.6E+00	3.0E-03	1.6E+00	3.0E-03
METHYL TERT BUTYL ETHER	2.3E-02	5.0E+00	2.3E-02	5.0E+00
METHYLENE CHLORIDE	1.1E-01	4.8E+00	1.1E-01	4.8E+00
METHYLNAPHTHALENE, 1-	2.4E+00	4.7E+00	1.1E+00	2.1E+00
METHYLNAPHTHALENE, 2-	5.0E+00	1.0E+01	1.0E+00	2.1E+00
MOLYBDENUM	4.0E+01	1.8E+02	4.0E+01	1.8E+02
NAPHTHALENE	4.6E-01	1.7E+01	4.6E-01	1.7E+01
NICKEL	1.5E+02	5.0E+00	1.5E+02	5.0E+00
NITROBENZENE	1.1E-01	3.4E+00	1.1E-01	3.4E+00
NITROGLYCERIN	7.9E-02	3.7E+00	7.9E-02	3.7E+00
NITROTOLUENE, 2-	3.2E-03	6.2E-02	3.2E-03	6.2E-02
NITROTOLUENE, 3-	6.7E+00	1.2E+02	6.7E+00	1.2E+02
NITROTOLUENE, 4-	2.2E-01	4.2E+00	2.2E-01	4.2E+00
PENTACHLOROPHENOL	5.6E-01	1.0E+00	5.6E-01	1.0E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	1.5E-02	6.1E-01	1.5E-02	6.1E-01
PERCHLORATE	7.0E-03	2.6E+01	7.0E-03	2.6E+01
PHENANTHRENE	1.8E+01	7.7E+00	1.1E+01	4.6E+00

**TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water**

CONTAMINANT	>150m to Surface Water Body		≤150m to Surface Water Body	
	¹ Soil (mg/kg)	² Groundwater (ug/L)	¹ Soil (mg/kg)	² Groundwater (ug/L)
PHENOL	2.2E-01	5.0E+00	2.2E-01	5.0E+00
POLYCHLORINATED BIPHENYLS (PCBs)	1.1E+00	5.0E-01	1.1E+00	1.4E-02
PROPICONAZOLE	1.6E+02	2.6E+02	2.4E+01	2.6E+01
PYRENE	5.6E+01	2.0E+00	5.6E+01	2.0E+00
SELENIUM	1.0E+01	2.0E+01	1.0E+01	5.0E+00
SILVER	2.0E+01	1.0E+00	2.0E+01	1.0E+00
SIMAZINE	9.9E-02	4.0E+00	4.9E-02	2.0E+00
STYRENE	1.0E+00	1.0E+01	1.0E+00	1.0E+01
TERBACIL	6.1E+00	4.7E+02	6.1E+00	4.7E+02
tert-BUTYL ALCOHOL	2.8E-02	4.5E+00	2.8E-02	4.5E+00
TETRACHLOROETHANE, 1,1,1,2-	1.6E-02	5.2E-01	1.6E-02	5.2E-01
TETRACHLOROETHANE, 1,1,2,2-	1.3E-03	6.7E-02	1.3E-03	6.7E-02
TETRACHLOROETHYLENE	7.0E-02	5.0E+00	7.0E-02	5.0E+00
TETRACHLOROPHENOL, 2,3,4,6-	3.3E+00	1.0E+01	4.0E-01	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	5.0E+02	1.8E+03	1.0E+02	3.3E+02
THALLIUM	1.0E+00	2.0E+00	1.0E+00	2.0E+00
TOLUENE	3.4E+00	4.0E+01	3.4E+00	4.0E+01
TOXAPHENE	4.4E-01	2.1E-01	4.4E-01	2.0E-04
TPH (gasolines)	1.0E+02	1.0E+02	1.0E+02	1.0E+02
TPH (middle distillates)	1.0E+02	1.0E+02	1.0E+02	1.0E+02
TPH (residual fuels)	5.0E+02	1.0E+02	5.0E+02	1.0E+02
TRICHLOROBENZENE, 1,2,4-	1.5E-01	7.0E+01	1.5E-01	2.5E+01
TRICHLOROETHANE, 1,1,1,-	2.3E+01	2.0E+02	7.1E+00	6.2E+01
TRICHLOROETHANE, 1,1,2,-	2.6E-02	5.0E+00	2.6E-02	5.0E+00
TRICHLOROETHYLENE	2.1E-01	5.0E+00	2.1E-01	5.0E+00
TRICHLOROPHENOL, 2,4,5-	1.0E+01	1.0E+02	2.2E+00	1.1E+01
TRICHLOROPHENOL, 2,4,6-	1.2E+00	6.1E+00	1.2E+00	6.1E+00
TRICHLOROPHOXYACETIC ACID, 2,4,5- (2,4,5-T)	2.9E+00	3.7E+02	2.9E+00	3.7E+02
TRICHLOROPHOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	4.0E-01	3.0E+01	4.0E-01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	1.4E-02	6.0E-01	1.4E-02	6.0E-01
TRICHLOROPROPENE, 1,2,3-	4.0E-01	2.2E+00	1.0E+01	6.1E+01
TRIFLURALIN	1.4E+01	8.7E+00	1.4E+01	8.7E+00
TRINITROBENZENE, 1,3,5-	2.5E+01	1.4E+02	5.4E+00	3.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	4.9E+01	1.5E+02	4.9E+01	1.5E+02
TRINITROTOLUENE, 2,4,6- (TNT)	6.8E-01	2.2E+00	6.8E-01	2.2E+00
VANADIUM	1.1E+02	1.9E+01	1.1E+02	1.9E+01

**TABLE A. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS Current or Potential Source of Drinking Water**

CONTAMINANT	>150m to Surface Water Body		≤150m to Surface Water Body	
	¹ Soil (mg/kg)	² Groundwater (ug/L)	¹ Soil (mg/kg)	² Groundwater (ug/L)
VINYL CHLORIDE	4.0E-02	2.0E+00	4.0E-02	2.0E+00
XYLENES	2.3E+00	2.0E+01	2.3E+00	2.0E+01
ZINC	6.0E+02	2.2E+01	6.0E+02	2.2E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	0.0E+00	4.0	0.0E+00
Sodium Adsorption Ratio	5.0	0.0E+00	12	0.0E+00

Notes:

1. Based on unrestricted current or future land use. Considered adequate for residential housing, schools, medical facilities, day-care centers, parks and other sensitive uses.
2. Assumes potential impacts to drinking water source and discharge of groundwater into a freshwater, marine or estuary surface water system.
3. Lead: First action level is based on ecotoxicity. Action level in parentheses is based on direct exposure to humans. Ecotoxicity action level generally not applicable to highly developed urban sites where no significant open spaces are anticipated.

Source of Soil Action Levels: Refer to Appendix 1, Tables A-1 and A-2.

Source of Groundwater Action Levels: Appendix 1, Table D-1a (≤150m to Surface Water Body) and Table D-1b (>150m to Surface Water Body).

Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).

Soil Action Levels intended to address direct-exposure, vapor intrusion, groundwater protection (leaching), ecologic (urban areas) and nuisance hazards. Soil gas data should be collected for additional evaluation of potential vapor intrusion hazards at sites with significant areas of VOC-impacted soil. See also Section 4.4 and Table C.

Groundwater Action Levels intended to address surface water impacts, vapor intrusion and nuisance hazards Use in conjunction with soil gas action levels to evaluate potential impacts to vapor intrusion hazards if groundwater action levels for this concern approached or exceeded (refer to Table C-1a in Appendix 1). See also Section 4.4 and Table C.

Groundwater action levels should be compared to dissolved phase chemical concentrations unless otherwise instructed by HDOH.

Groundwater ALs >150m to Surface Water Body: Groundwater screened with respect to acute surface water goals (See Table D-1b).

Groundwater ALs ≤150m to Surface Water Body: Groundwater screened with respect to chronic surface water goals (see Table D-1a).

TPH -Total Petroleum Hydrocarbons: TPH Action Levels must be used in conjunction with Action Levels for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Section 2.6 in text.

TPH soil action levels for gross contamination hazards in isolated soils may be used as final cleanup levels if soil situated >3m deep at residential site and >1m (or otherwise capped) at commercial sites AND site data indicate that remaining contamination will not pose leaching or vapor intrusion hazards (refer to Table F-3 in Appendix 1; TPHg = 4,500 mg/kg, TPHmd & TPHrf = 5,000 mg/kg). TPH soil action levels noted in above table should be applied at sites with elevated threats to drinking water resources or aquatic habitats. Refer to Section 2.6 in text.

**TABLE B: GROUNDWATER IS NOT A CURRENT OR
POTENTIAL SOURCE OF DRINKING
WATER**

**TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water**

CONTAMINANT	>150m to Surface Water Body		≤150m to Surface Water Body	
	¹ Soil (mg/kg)	² Groundwater (ug/L)	¹ Soil (mg/kg)	² Groundwater (ug/L)
ACENAPHTHENE	1.4E+02	2.0E+02	2.3E+01	2.3E+01
ACENAPHTHYLENE	1.3E+02	3.0E+02	1.3E+01	3.0E+01
ACETONE	8.6E-01	1.5E+03	8.6E-01	1.5E+03
ALDRIN	2.9E-02	1.3E+00	2.9E-02	1.3E-01
AMETRYN	1.1E+01	1.5E+02	1.1E+00	1.5E+01
AMINO,2- DINITROTOLUENE,4,6-	2.5E+00	1.5E+02	2.5E-01	1.5E+01
AMINO,4- DINITROTOLUENE,2,6-	2.5E+00	1.5E+02	2.5E-01	1.5E+01
ANTHRACENE	2.5E+00	7.3E-01	2.5E+00	7.3E-01
ANTIMONY	6.3E+00	1.5E+03	6.3E+00	3.0E+01
ARSENIC	2.0E+01	6.9E+01	2.0E+01	3.6E+01
ATRAZINE	2.1E+00	3.5E+02	4.6E-01	1.2E+01
BARIUM	7.5E+02	2.0E+03	7.5E+02	2.0E+03
BENZENE	5.3E-01	1.5E+03	5.3E-01	4.6E+01
BENZO(a)ANTHRACENE	1.5E+00	2.7E-02	1.5E+00	2.7E-02
BENZO(a)PYRENE	1.5E-01	1.4E-02	1.5E-01	1.4E-02
BENZO(b)FLUORANTHENE	1.5E+00	9.2E-02	1.5E+00	9.2E-02
BENZO(g,h,i)PERYLENE	2.7E+01	1.0E-01	2.7E+01	1.0E-01
BENZO(k)FLUORANTHENE	1.5E+01	4.0E-01	1.5E+01	4.0E-01
BERYLLIUM	4.0E+00	4.3E+01	4.0E+00	2.7E+00
BIPHENYL, 1,1-	5.2E+00	5.0E+00	5.2E+00	5.0E+00
BIS(2-CHLOROETHYL)ETHER	2.6E-03	1.1E+02	2.6E-03	6.1E+01
BIS(2-CHLOROISOPROPYL)ETHER	3.3E+00	3.2E+03	6.6E-01	6.1E+01
BIS(2-ETHYLHEXYL)PHTHALATE	3.5E+01	3.2E+01	3.5E+01	3.2E+01
BORON	1.0E+02	7.3E+03	1.0E+02	7.3E+03
BROMODICHLOROMETHANE	2.3E-02	1.6E+02	2.3E-02	1.6E+02
BROMOFORM	4.7E+01	5.1E+03	2.9E+01	3.2E+03
BROMOMETHANE	1.8E-01	3.6E+02	1.8E-01	1.6E+02
CADMIUM	1.2E+01	3.0E+00	1.2E+01	3.0E+00
CARBON TETRACHLORIDE	2.7E-02	3.1E+01	2.7E-02	9.8E+00
CHLORDANE (TECHNICAL)	1.6E+01	9.0E-02	1.6E+01	4.0E-03
CHLOROANILINE, p-	6.0E-02	5.0E+00	6.0E-02	5.0E+00
CHLOROBENZENE	1.8E+00	1.6E+02	1.6E+00	2.5E+01
CHLOROETHANE	2.8E-01	3.9E+00	1.2E+01	1.6E+02
CHLOROFORM	1.8E-02	7.4E+01	1.8E-02	7.4E+01
CHLOROMETHANE	2.3E-01	2.9E+02	2.3E-01	2.9E+02
CHLOROPHENOL, 2-	1.3E-01	1.8E+00	1.3E-01	1.8E+00
CHROMIUM (Total)	5.0E+02	5.7E+02	5.0E+02	7.4E+01
CHROMIUM III	7.5E+02	5.7E+02	7.5E+02	7.4E+01
CHROMIUM VI	8.0E+00	1.6E+01	8.0E+00	1.1E+01
CHRYSENE	1.4E+01	3.5E-01	1.4E+01	3.5E-01
COBALT	4.0E+01	3.0E+00	4.0E+01	3.0E+00
COPPER	2.3E+02	2.9E+00	2.3E+02	2.9E+00
CYANIDE (Free)	1.0E+02	1.0E+00	1.0E+02	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	5.5E+00	1.4E+03	5.5E+00	1.9E+02
DALAPON	1.4E+00	3.0E+03	1.4E-01	3.0E+02
DIBENZO(a,h)ANTHTRACENE	1.5E-01	5.2E-01	1.5E-01	5.2E-01
DIBROMO,1,2- CHLOROPROPANE,3-	9.0E-04	4.0E-02	9.0E-04	4.0E-02
DIBROMOCHLOROMETHANE	1.7E-02	2.7E+02	1.7E-02	2.7E+02
DIBROMOETHANE, 1,2-	6.9E-04	1.2E+01	6.9E-04	1.2E+01
DICHLOROBENZENE, 1,2-	7.1E+00	1.0E+02	1.2E+00	1.4E+01
DICHLOROBENZENE, 1,3-	3.0E+01	3.7E+02	7.4E+00	6.5E+01
DICHLOROBENZENE, 1,4-	3.7E-02	1.1E+02	3.7E-02	1.5E+01
DICHLOROBENZIDINE, 3,3-	1.1E+00	2.5E+02	1.1E+00	2.5E+02
DICHLORODIPHENYLDICHLOROETHANE (DDD)	2.0E+00	6.0E-01	2.0E+00	1.0E-03
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	1.4E+00	1.1E+00	1.4E+00	1.0E-03
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	1.7E+00	1.3E-02	1.7E+00	1.0E-03
DICHLOROETHANE, 1,1-	2.6E-01	4.7E+01	2.6E-01	4.7E+01
DICHLOROETHANE, 1,2-	1.6E-02	1.2E+02	1.6E-02	1.2E+02
DICHLOROETHYLENE, 1,1-	7.1E+00	3.9E+03	4.3E+00	2.5E+01

**TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water**

CONTAMINANT	>150m to Surface Water Body		≤150m to Surface Water Body	
	¹ Soil (mg/kg)	² Groundwater (ug/L)	¹ Soil (mg/kg)	² Groundwater (ug/L)
DICHLOROETHYLENE, Cis 1,2-	1.2E+00	4.3E+03	1.2E+00	5.9E+02
DICHLOROETHYLENE, Trans 1,2-	2.1E+00	2.6E+03	2.1E+00	5.9E+02
DICHLOROPHENOL, 2,4-	3.6E-01	3.0E+00	3.6E-01	3.0E+00
DICHLOROPHENOXYACETIC ACID (2,4-D)	9.8E-01	2.0E+02	2.0E-01	4.0E+01
DICHLOROPROPANE, 1,2-	4.1E-02	1.0E+02	4.1E-02	1.0E+02
DICHLOROPROPENE, 1,3-	1.0E-01	2.6E+02	1.0E-01	1.2E+02
DIELDRIN	3.0E-02	7.1E-01	3.3E-03	1.9E-03
DIETHYLPHTHALATE	2.0E+01	9.4E+02	3.1E-02	1.5E+00
DIMETHYLPHENOL, 2,4-	3.2E+01	2.7E+02	1.3E+01	1.1E+02
DIMETHYLPHTHALATE	2.2E+01	9.4E+02	3.5E-02	1.5E+00
DINITROBENZENE, 1,3-	1.2E+00	1.1E+02	1.1E+00	3.0E+01
DINITROPHENOL, 2,4-	1.4E+01	2.3E+02	4.5E+00	7.5E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	6.6E+00	1.1E+02	2.7E+00	4.4E+01
DINITROTOLUENE, 2,6- (2,6-DNT)	6.8E+00	1.1E+02	2.7E+00	4.4E+01
DIOXANE, 1,4-	9.8E+00	5.0E+04	9.8E+00	5.0E+04
DIOXINS (TEQ)	4.5E-06	3.0E-03	4.5E-06	5.0E-06
DIURON	4.5E+00	2.0E+02	1.4E+00	6.0E+01
ENDOSULFAN	1.2E-01	3.4E-02	3.2E-02	8.7E-03
ENDRIN	6.0E-02	3.7E-02	4.0E-03	2.3E-03
ETHANOL	4.5E+00	5.0E+04	4.5E+00	5.0E+04
ETHYLBENZENE	1.6E+00	3.0E+02	1.6E+00	2.9E+02
FLUORANTHENE	4.0E+01	4.0E+01	4.0E+01	8.0E+00
FLUORENE	1.3E+02	3.0E+02	7.3E+00	3.9E+00
GLYPHOSATE	1.9E+00	6.0E+02	2.0E-01	6.5E+01
HEPTACHLOR	1.1E-01	5.3E-02	1.1E-01	3.6E-03
HEPTACHLOR EPOXIDE	4.6E-02	5.3E-02	3.1E-03	3.6E-03
HEXACHLOROBENZENE	3.0E-01	3.1E+00	3.0E-01	3.1E+00
HEXACHLOROBUTADIENE	2.5E+00	1.1E+01	1.1E+00	4.7E+00
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	9.0E-02	1.6E-01	4.5E-02	8.0E-02
HEXACHLOROETHANE	6.2E+00	1.0E+02	7.4E-01	1.2E+01
HEXAZINONE	4.0E+02	5.0E+04	4.0E+02	5.0E+03
INDENO(1,2,3-cd)PYRENE	1.5E+00	9.2E-02	1.5E+00	9.2E-02
ISOPHORONE	4.2E+01	4.3E+03	1.3E+00	1.3E+02
LEAD	2.0E+02	2.9E+01	2.0E+02	5.6E+00
MERCURY	4.7E+00	2.1E+00	4.7E+00	2.5E-02
METHOXYCHLOR	2.6E+01	3.0E-02	2.6E+01	3.0E-02
METHYL ETHYL KETONE	1.4E+01	1.4E+04	1.4E+01	1.4E+04
METHYL ISOBUTYL KETONE	4.5E-01	1.7E+02	4.5E-01	1.7E+02
METHYL MERCURY	1.6E+00	3.0E-03	1.6E+00	3.0E-03
METHYL TERT BUTYL ETHER	1.6E+00	1.8E+03	1.6E+00	1.8E+03
METHYLENE CHLORIDE	8.8E-01	3.1E+03	8.8E-01	2.2E+03
METHYLNAPHTHALENE, 1-	2.6E+00	1.0E+02	1.1E+00	2.1E+00
METHYLNAPHTHALENE, 2-	2.5E+01	1.0E+02	1.0E+00	2.1E+00
MOLYBDENUM	4.0E+01	2.4E+02	4.0E+01	2.4E+02
NAPHTHALENE	4.6E-01	2.1E+02	4.6E-01	2.4E+01
NICKEL	1.5E+02	5.0E+00	1.5E+02	5.0E+00
NITROBENZENE	6.2E+00	2.0E+03	1.9E+00	6.0E+01
NITROGLYCERIN	1.2E+00	1.4E+02	1.2E+00	1.4E+02
NITROTOLUENE, 2-	1.9E+00	7.5E+03	1.9E+00	1.0E+03
NITROTOLUENE, 3-	2.1E+02	3.8E+03	2.1E+01	3.8E+02
NITROTOLUENE, 4-	3.0E+01	3.3E+03	3.0E+01	1.6E+03
PENTACHLOROPHENOL	3.0E+00	1.3E+01	3.0E+00	7.9E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	4.4E+00	2.2E+04	4.4E+00	2.2E+04
PERCHLORATE	1.2E+00	6.0E+02	1.2E+00	6.0E+02
PHENANTHRENE	1.8E+01	7.7E+00	1.1E+01	4.6E+00

**TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water**

CONTAMINANT	>150m to Surface Water Body		≤150m to Surface Water Body	
	¹ Soil (mg/kg)	² Groundwater (ug/L)	¹ Soil (mg/kg)	² Groundwater (ug/L)
PHENOL	4.0E+01	3.4E+03	4.0E+01	1.3E+03
POLYCHLORINATED BIPHENYLS (PCBs)	1.1E+00	2.0E+00	1.1E+00	1.4E-02
PROPICONAZOLE	1.6E+02	2.6E+02	2.4E+01	2.6E+01
PYRENE	5.6E+01	2.0E+00	5.6E+01	2.0E+00
SELENIUM	1.0E+01	2.0E+01	1.0E+01	5.0E+00
SILVER	2.0E+01	1.0E+00	2.0E+01	1.0E+00
SIMAZINE	2.5E-01	1.0E+01	4.9E-02	2.0E+00
STYRENE	1.0E+01	1.0E+02	1.0E+01	1.0E+02
TERBACIL	1.6E+02	2.3E+04	3.0E+01	2.3E+03
tert-BUTYL ALCOHOL	8.1E+01	5.0E+04	8.1E+01	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	2.0E+00	3.1E+03	2.0E+00	3.1E+02
TETRACHLOROETHANE, 1,1,2,2-	7.1E-03	1.6E+02	7.1E-03	1.6E+02
TETRACHLOROETHYLENE	7.0E-02	1.4E+02	7.0E-02	1.2E+02
TETRACHLOROPHENOL, 2,3,4,6-	3.3E+00	1.0E+01	4.0E-01	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	5.0E+02	1.9E+03	1.0E+02	3.3E+02
THALLIUM	1.0E+00	4.7E+02	1.0E+00	2.0E+01
TOLUENE	3.4E+01	4.0E+02	1.1E+01	1.3E+02
TOXAPHENE	4.4E-01	2.1E-01	4.4E-01	2.0E-04
TPH (gasolines)	1.0E+02	5.0E+03	1.0E+02	5.0E+02
TPH (middle distillates)	5.0E+02	2.5E+03	5.0E+02	6.4E+02
TPH (residual fuels)	5.0E+02	2.5E+03	5.0E+02	6.4E+02
TRICHLOROBENZENE, 1,2,4-	1.5E-01	1.6E+02	1.5E-01	2.5E+01
TRICHLOROETHANE, 1,1,1-	1.8E+02	6.0E+03	7.1E+00	6.2E+01
TRICHLOROETHANE, 1,1,2-	2.6E-02	3.0E+02	2.6E-02	3.0E+02
TRICHLOROETHYLENE	2.1E-01	4.8E+02	2.1E-01	3.6E+02
TRICHLOROPHENOL, 2,4,5-	1.0E+01	1.0E+02	2.2E+00	1.1E+01
TRICHLOROPHENOL, 2,4,6-	1.0E+01	4.9E+02	1.0E+01	4.9E+02
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	5.5E+00	6.9E+02	5.5E+00	6.9E+02
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	4.0E-01	3.0E+01	4.0E-01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	1.8E-02	1.4E+02	1.8E-02	1.4E+01
TRICHLOROPROPENE, 1,2,3-	4.0E-01	2.2E+00	1.0E+01	1.5E+02
TRIFLURALIN	3.2E+01	2.0E+01	3.2E+01	2.0E+01
TRINITROBENZENE, 1,3,5-	2.5E+01	1.4E+02	5.4E+00	3.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	4.9E+01	1.5E+02	4.9E+01	1.5E+02
TRINITROTOLUENE, 2,4,6- (TNT)	7.2E+00	5.7E+02	7.2E+00	1.3E+02
VANADIUM	1.1E+02	1.9E+01	1.1E+02	1.9E+01

**TABLE B. ENVIRONMENTAL ACTION LEVELS (EALs)
Groundwater IS NOT Current or Potential Source of Drinking Water**

CONTAMINANT	>150m to Surface Water Body		≤150m to Surface Water Body	
	¹ Soil (mg/kg)	² Groundwater (ug/L)	¹ Soil (mg/kg)	² Groundwater (ug/L)
VINYL CHLORIDE	4.0E-02	2.1E+01	4.0E-02	2.1E+01
XYLENES	1.2E+02	1.0E+03	1.2E+01	1.0E+02
ZINC	6.0E+02	2.2E+01	6.0E+02	2.2E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	2.0	0.0E+00	4.0	0.0E+00
Sodium Adsorption Ratio	5.0	0.0E+00	12	0.0E+00

Notes:

1. Based on unrestricted current or future land use. Considered adequate for residential housing, schools, medical facilities, day-care centers, parks and other sensitive uses.
2. Assumes potential discharge of groundwater into a freshwater, marine or estuary surface water system.

Source of Soil Action Levels: Refer to Appendix 1, Tables B-1 and B-2.

Source of Groundwater Action Levels: Appendix 1, Table D-1c (≤150m to Surface Water Body) and Table D-1d (>150m to Surface Water Body).

Soil data should be reported on dry-weight basis (see Appendix 1, Section 6.2).

Soil Action Levels intended to address direct-exposure, vapor intrusion, groundwater protection (leaching), ecologic (urban areas) and nuisance hazards. Soil gas data should be collected for additional evaluation of potential vapor intrusion hazards at sites with significant areas of VOC-impacted soil. See also Section 4.4 and Table C.

Groundwater Action Levels intended to address surface water impacts, vapor intrusion and nuisance concerns. Use in conjunction with soil gas action levels to evaluate potential impacts to vapor intrusion hazards if groundwater action levels for this concern approached or exceeded (refer to Table C-1a in Appendix 1). See also Section 4.4 and Table C.

Groundwater action levels should be compared to dissolved phase chemical concentrations unless otherwise instructed by HDOH.

Groundwater ALs >150m to Surface Water Body: Groundwater screened with respect to acute surface water goals (See Table D-1d).

Groundwater ALs ≤150m to Surface Water Body: Groundwater screened with respect to chronic surface water goals (see Table D-1c).

TPH -Total Petroleum Hydrocarbons: TPH Action Levels must be used in conjunction with Action Levels for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Section 2.6 in text.

TPH soil action levels for gross contamination hazards in isolated soils may be used as final cleanup levels if soil situated >3m deep at residential site and >1m (or otherwise capped) at commercial sites AND site data indicate that remaining contamination will not pose leaching or vapor intrusion hazards (refer to Table F-3 in Appendix 1; TPHg = 4,500 mg/kg, TPHmd & TPHrf = 5,000 mg/kg). TPH soil action levels noted in above table should be applied at sites with elevated threats to drinking water resources or aquatic habitats. Refer to Section 2.6 in text.

TABLE C: INDOOR AIR AND SOIL GAS

**TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Gas
(Vapor Intrusion Hazards)**

CHEMICAL PARAMETER	Physical State		INDOOR AIR ACTION LEVELS		² SHALLOW SOIL GAS ACTION LEVELS	
			¹ Residential (ug/m ³)	Commercial/Industrial (ug/m ³)	¹ Residential (ug/m ³)	Commercial/Industrial (ug/m ³)
ACENAPHTHENE	V	S	4.4E+01	6.1E+01	4.4E+04	1.2E+05
ACENAPHTHYLENE	V	S	2.9E+01	4.1E+01	2.9E+04	8.2E+04
ACETONE	V	L	6.5E+03	9.1E+03	6.5E+06	1.8E+07
ALDRIN	NV	S				
AMETRYN	NV	S				
AMINO,2- DINITROTOLUENE,4,6-	NV	S				
AMINO,4- DINITROTOLUENE,2,6-	NV	S				
ANTHRACENE	V	S	2.2E+02	3.1E+02	2.2E+05	6.1E+05
ANTIMONY	NV	S				
ARSENIC	NV	S				
ATRAZINE	NV	S				
BARIUM	NV	S				
BENZENE	V	L	2.5E-01	5.2E-01	2.5E+02	1.0E+03
BENZO(a)ANTHRACENE	NV	S				
BENZO(a)PYRENE	NV	S				
BENZO(b)FLUORANTHENE	NV	S				
BENZO(g,h,i)PERYLENE	NV	S				
BENZO(k)FLUORANTHENE	NV	S				
BERYLLIUM	NV	S				
BIPHENYL, 1,1-	V	S	3.7E+01	5.1E+01	3.7E+04	1.0E+05
BIS(2-CHLOROETHYL)ETHER	V	L	5.8E-03	1.2E-02	5.8E+00	2.5E+01
BIS(2-CHLOROISOPROPYL)ETHER	V	L	1.9E-01	4.1E-01	1.9E+02	8.2E+02
BIS(2-ETHYLHEXYL)PHTHALATE	NV	S				
BORON	NV	S				
BROMODICHLOROMETHANE	V	L	1.1E-01	2.3E-01	1.1E+02	4.6E+02
BROMOFORM	NV	S				
BROMOMETHANE	V	G	1.0E+00	1.5E+00	1.0E+03	2.9E+03
CADMIUM	NV	S				
CARBON TETRACHLORIDE	V	L	1.3E-01	2.7E-01	1.3E+02	5.5E+02
CHLORDANE (TECHNICAL)	NV	S				
CHLOROANILINE, p-	NV	S				
CHLOROBENZENE	V	L	1.0E+01	1.5E+01	1.0E+04	2.9E+04
CHLOROETHANE	V	G	2.1E+03	2.9E+03	2.1E+06	5.8E+06
CHLOROFORM	V	L	8.4E-02	1.8E-01	8.4E+01	3.6E+02
CHLOROMETHANE	V	G	1.1E+00	2.3E+00	1.1E+03	4.5E+03
CHLOROPHENOL, 2-	V	L	3.7E+00	5.1E+00	3.7E+03	1.0E+04
CHROMIUM (Total)	NV	S				
CHROMIUM III	NV	S				
CHROMIUM VI	NV	S				
CHRYSENE	NV	S				
COBALT	NV	S				
COPPER	NV	S				
CYANIDE (Free)	V	S				
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	NV	S				
DALAPON	NV	L				
DIBENZO(a,h)ANTHRACENE	NV	S				
DIBROMO,1,2- CHLOROPROPANE,3-	V	L	3.2E-04	6.8E-04	3.2E-01	1.4E+00
DIBROMOCHLOROMETHANE	V	S	8.0E-02	1.7E-01	8.0E+01	3.4E+02
DIBROMOETHANE, 1,2-	V	S	3.2E-03	6.8E-03	3.2E+00	1.4E+01
DICHLOROBENZENE, 1,2-	V	L	4.2E+01	5.8E+01	4.2E+04	1.2E+05
DICHLOROBENZENE, 1,3-	V	L	2.2E+01	3.1E+01	2.2E+04	6.1E+04
DICHLOROBENZENE, 1,4-	V	S	1.7E-01	3.7E-01	1.7E+02	7.4E+02
DICHLOROBENZIDINE, 3,3-	NV	S				
DICHLORODIPHENYLDICHLOROETHANE (DDD)	NV	S				
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	NV	S				
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	NV	S				
DICHLOROETHANE, 1,1-	V	L	1.2E+00	2.6E+00	1.2E+03	5.1E+03

**TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Gas
(Vapor Intrusion Hazards)**

CHEMICAL PARAMETER	Physical State		INDOOR AIR ACTION LEVELS		² SHALLOW SOIL GAS ACTION LEVELS	
			¹ Residential (ug/m ³)	Commercial/Industrial (ug/m ³)	¹ Residential (ug/m ³)	Commercial/Industrial (ug/m ³)
DICHLOROETHANE, 1,2-	V	L	7.4E-02	1.6E-01	7.4E+01	3.1E+02
DICHLOROETHYLENE, 1,1-	V	L	4.2E+01	5.8E+01	4.2E+04	1.2E+05
DICHLOROETHYLENE, Cis 1,2-	V	L	7.3E+00	1.0E+01	7.3E+03	2.0E+04
DICHLOROETHYLENE, Trans 1,2-	V	L	1.3E+01	1.8E+01	1.3E+04	3.5E+04
DICHLOROPHENOL, 2,4-	NV	S				
DICHLOROPHENOXYACETIC ACID (2,4-D)	NV	S				
DICHLOROPROPANE, 1,2-	V	L	1.9E-01	4.1E-01	1.9E+02	8.2E+02
DICHLOROPROPENE, 1,3-	V	L	4.8E-01	1.0E+00	4.8E+02	2.0E+03
DIELDRIN	NV	S				
DIETHYLPHTHALATE	NV	S				
DIMETHYLPHENOL, 2,4-	V	S	1.5E+01	2.0E+01	1.5E+04	4.1E+04
DIMETHYLPHTHALATE	NV	S				
DINITROBENZENE, 1,3-	NV	S				
DINITROPHENOL, 2,4-	NV	S				
DINITROTOLUENE, 2,4- (2,4-DNT)	NV	S				
DINITROTOLUENE, 2,6- (2,6-DNT)	NV	S				
DIOXANE, 1,4-	NV	L				
DIOXINS (TEQ)	NV	S				
DIURON	NV	S				
ENDOSULFAN	NV	S				
ENDRIN	NV	S				
ETHANOL	NV	L				
ETHYLBENZENE	V	L	7.7E-01	1.6E+00	7.7E+02	3.3E+03
FLUORANTHENE	NV	S				
FLUORENE	V	S	2.9E+01	4.1E+01	2.9E+04	8.2E+04
GLYPHOSATE	NV	S				
HEPTACHLOR	NV	S				
HEPTACHLOR EPOXIDE	NV	S				
HEXACHLOROENZENE	NV	S				
HEXACHLOROBUTADIENE	NV	S				
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	NV	S				
HEXACHLOROETHANE	NV	S				
HEXAZINONE	NV	S				
INDENO(1,2,3-cd)PYRENE	NV	S				
ISOPHORONE	NV	L				
LEAD	NV	S				
MERCURY	V	S				
METHOXYCHLOR	NV	S				
METHYL ETHYL KETONE	V	L	1.0E+03	1.5E+03	1.0E+06	2.9E+06
METHYL ISOBUTYL KETONE	V	L	6.3E+02	8.8E+02	6.3E+05	1.8E+06
METHYL MERCURY	NV	S				
METHYL TERT BUTYL ETHER	V	L	7.4E+00	1.6E+01	7.4E+03	3.1E+04
METHYLENE CHLORIDE	V	L	4.1E+00	8.7E+00	4.1E+03	1.7E+04
METHYLNAPHTHALENE, 1-	V	S	2.3E-01	4.9E-01	2.3E+02	9.9E+02
METHYLNAPHTHALENE, 2-	V	S	2.9E+00	4.1E+00	2.9E+03	8.2E+03
MOLYBDENUM	NV	S				
NAPHTHALENE	V	S	5.7E-02	1.2E-01	5.7E+01	2.4E+02
NICKEL	NV	S				
NITROBENZENE	V	L	4.2E-01	5.8E-01	4.2E+02	1.2E+03
NITROGLYCERIN	NV	L				
NITROTOLUENE, 2-	V	S	3.1E-02	6.5E-02	3.1E+01	1.3E+02
NITROTOLUENE, 3-	V	S	1.5E+01	2.0E+01	1.5E+04	4.1E+04
NITROTOLUENE, 4-	NV	S				

**TABLE C. ENVIRONMENTAL ACTION LEVELS (EALs)
Indoor Air and Soil Gas
(Vapor Intrusion Hazards)**

CHEMICAL PARAMETER	Physical State		INDOOR AIR ACTION LEVELS		² SHALLOW SOIL GAS ACTION LEVELS	
			¹ Residential (ug/m ³)	Commercial/Industrial (ug/m ³)	¹ Residential (ug/m ³)	Commercial/Industrial (ug/m ³)
PENTACHLOROPHENOL	NV	S				
PENTAERYTHRITOLTETRANITRATE (PETN)	NV	S				
PERCHLORATE	NV	S				
PHENANTHRENE	V	S	2.9E+01	4.1E+01	2.9E+04	8.2E+04
PHENOL	NV	S				
POLYCHLORINATED BIPHENYLS (PCBs)	NV	S				
PROPIONAZOLE	NV	L				
PYRENE	V	S	2.2E+01	3.1E+01	2.2E+04	6.1E+04
SELENIUM	NV	S				
SILVER	NV	S				
SIMAZINE	NV	S				
STYRENE	V	L	2.1E+02	2.9E+02	2.1E+05	5.8E+05
TERBACIL	NV	S				
tert-BUTYL ALCOHOL	V	L	2.2E+00	4.8E+00	2.2E+03	9.5E+03
TETRACHLOROETHANE, 1,1,1,2-	V	L	2.6E-01	5.5E-01	2.6E+02	1.1E+03
TETRACHLOROETHANE, 1,1,2,2-	V	L	3.3E-02	7.0E-02	3.3E+01	1.4E+02
TETRACHLOROETHYLENE	V	L	3.3E-01	6.9E-01	3.3E+02	1.4E+03
TETRACHLOROPHENOL, 2,3,4,6-	NV	S				
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	NV	S				
THALLIUM	NV	S				
TOLUENE	V	L	1.0E+03	1.5E+03	1.0E+06	2.9E+06
TOXAPHENE	NV	S				
TPH (gasolines)	V	L	2.6E+01	3.7E+01	2.6E+04	7.3E+04
TPH (middle distillates)	V	L	5.7E+01	8.0E+01	5.7E+04	1.6E+05
TPH (residual fuels)	NV	L				
TRICHLOROENZENE, 1,2,4-	V	S	8.3E-01	1.2E+00	8.3E+02	2.3E+03
TRICHLOROETHANE, 1,1,1-	V	L	1.0E+03	1.5E+03	1.0E+06	2.9E+06
TRICHLOROETHANE, 1,1,2-	V	L	1.2E-01	2.6E-01	1.2E+02	5.1E+02
TRICHLOROETHYLENE	V	L	9.6E-01	2.0E+00	9.6E+02	4.1E+03
TRICHLOROPHENOL, 2,4,5-	NV	S				
TRICHLOROPHENOL, 2,4,6-	NV	S				
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	NV	S				
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	NV	S				
TRICHLOROPROPANE, 1,2,3-	V	L	9.6E-04	2.0E-03	9.6E-01	4.1E+00
TRICHLOROPROPENE, 1,2,3-	V	L	7.3E+00	1.0E+01	7.3E+03	2.0E+04
TRIFLURALIN	NV	S				
TRINITROENZENE, 1,3,5-	NV	S				
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	NV	S				
TRINITROTOLUENE, 2,4,6- (TNT)	NV	S				
VANADIUM	NV	S				
VINYL CHLORIDE	V	G	4.4E-01	9.3E-01	4.4E+02	1.9E+03
XYLENES	V	L	1.5E+02	2.0E+02	1.5E+05	4.1E+05
ZINC	NV	S				
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)			not applicable	not applicable	not applicable	not applicable
Sodium Adsorption Ratio			not applicable	not applicable	not applicable	not applicable

Notes:
1. Category "Residential" considered adequate for other sensitive uses (e.g., day-care centers, hospitals, etc.)
2. Soil Gas: Screening levels based on soil gas data collected immediately beneath a building slab or within 1.5 meters (five feet) ground surface in open areas. Intended for evaluation of potential vapor intrusion hazards.
Soil gas action levels apply to areas that overlie contaminated soil and/or contaminated groundwater.

TPH -Total Petroleum Hydrocarbons. TPH (or equivalent) must be included in analyses for soil gas collected at petroleum release sites, in addition to individual, targeted VOCs(e.g., BTEX, etc.). See Volume 1, Section 2.6 and Appendix 1, Chapter 5.

TABLE D: SUMMARY OF DRINKING WATER GOALS

TABLE D. ENVIRONMENTAL ACTION LEVELS (EALs)

¹Surface Water Bodies

CHEMICAL PARAMETER	SURFACE WATER ACTION LEVELS		
	² Freshwater (ug/L)	³ Marine (ug/L)	⁴ Estuarine (ug/L)
ACENAPHTHENE	2.0E+01	2.0E+01	2.0E+01
ACENAPHTHYLENE	3.0E+01	3.0E+01	3.0E+01
ACETONE	1.5E+03	1.5E+03	1.5E+03
ALDRIN	2.6E-05	2.6E-05	2.6E-05
AMETRYN	1.5E+01	1.5E+01	1.5E+01
AMINO,2- DINITROTOLUENE,4,6-	1.5E+01	1.5E+01	1.5E+01
AMINO,4- DINITROTOLUENE,2,6-	1.5E+01	1.5E+01	1.5E+01
ANTHRACENE	7.3E-01	7.3E-01	7.3E-01
ANTIMONY	6.0E+00	5.0E+02	3.0E+01
ARSENIC	1.4E-01	1.4E-01	1.4E-01
ATRAZINE	3.0E+00	2.6E+01	1.2E+01
BARIUM	2.0E+03	2.0E+03	2.0E+03
BENZENE	5.0E+00	1.3E+01	1.3E+01
BENZO(a)ANTHRACENE	1.8E-02	1.8E-02	1.8E-02
BENZO(a)PYRENE	1.4E-02	1.4E-02	1.4E-02
BENZO(b)FLUORANTHENE	1.8E-02	1.8E-02	1.8E-02
BENZO(g,h,i)PERYLENE	1.0E-01	1.0E-01	1.0E-01
BENZO(k)FLUORANTHENE	1.8E-02	1.8E-02	1.8E-02
BERYLLIUM	3.8E-02	3.8E-02	3.8E-02
BIPHENYL, 1,1-	5.0E-01	5.0E-01	5.0E-01
BIS(2-CHLOROETHYL)ETHER	1.2E-02	4.4E-01	4.4E-01
BIS(2-CHLOROISOPROPYL)ETHER	3.2E-01	6.1E+01	6.1E+01
BIS(2-ETHYLHEXYL)PHTHALATE	2.2E+00	2.2E+00	2.2E+00
BORON	4.1E+01	7.3E+03	7.3E+03
BROMODICHLOROMETHANE	2.2E-01	3.2E+03	3.2E+03
BROMOFORM	1.0E+02	1.4E+02	1.4E+02
BROMOMETHANE	8.7E+00	1.5E+03	1.6E+02
CADMIUM	3.0E+00	9.3E+00	3.0E+00
CARBON TETRACHLORIDE	2.3E+00	2.3E+00	2.3E+00
CHLORDANE (TECHNICAL)	1.6E-05	1.6E-05	1.6E-05
CHLOROANILINE, p-	1.2E+00	5.0E+00	5.0E+00
CHLOROBENZENE	2.5E+01	5.0E+01	2.5E+01
CHLOROETHANE	1.6E+01	1.6E+01	1.6E+01
CHLOROFORM	5.1E+00	5.1E+00	5.1E+00
CHLOROMETHANE	1.8E+00	3.2E+03	3.2E+03
CHLOROPHENOL, 2-	1.8E-01	1.8E-01	1.8E-01
CHROMIUM (Total)	7.4E+01	1.0E+04	7.4E+01
CHROMIUM III	7.4E+01	7.4E+01	7.4E+01
CHROMIUM VI	2.1E-01	5.0E+01	1.1E+01
CHRYSENE	1.8E-02	1.8E-02	1.8E-02
COBALT	4.2E-02	3.0E+00	3.0E+00
COPPER	6.0E+00	2.9E+00	2.9E+00
CYANIDE (Free)	5.2E+00	1.0E+00	1.0E+00
CYCLO-1,3,5-TRIMETHYLENE-2,4,6-TRINITRAMINE (RDX)	6.1E-01	1.9E+02	1.9E+02
DALAPON	2.0E+02	3.0E+02	3.0E+02
DIBENZO(a,h)ANTHRACENE	9.2E-03	1.8E-02	1.8E-02
DIBROMO,1,2- CHLOROPROPANE,3-	4.0E-02	4.0E-02	4.0E-02

TABLE D. ENVIRONMENTAL ACTION LEVELS (EALs)

¹Surface Water Bodies

CHEMICAL PARAMETER	SURFACE WATER ACTION LEVELS		
	² Freshwater (ug/L)	³ Marine (ug/L)	⁴ Estuarine (ug/L)
DIBROMOCHLOROMETHANE	1.6E-01	1.3E+01	1.3E+01
DIBROMOETHANE, 1,2-	6.5E-03	1.4E+03	1.4E+03
DICHLOROBENZENE, 1,2-	1.0E+01	1.0E+01	1.0E+01
DICHLOROBENZENE, 1,3-	7.1E+01	6.5E+01	6.5E+01
DICHLOROBENZENE, 1,4-	5.0E+00	1.1E+01	1.1E+01
DICHLOROBENZIDINE, 3,3-	7.0E-03	7.0E-03	7.0E-03
DICHLORODIPHENYLDICHLOROETHANE (DDD)	3.1E-04	3.1E-04	3.1E-04
DICHLORODIPHENYLDICHLOROETHYLENE (DDE)	2.2E-04	2.2E-04	2.2E-04
DICHLORODIPHENYLTRICHLOROETHANE (DDT)	8.0E-06	8.0E-06	8.0E-06
DICHLOROETHANE, 1,1-	2.4E+00	4.7E+01	4.7E+01
DICHLOROETHANE, 1,2-	1.5E-01	7.9E+01	7.9E+01
DICHLOROETHYLENE, 1,1-	6.0E-01	6.0E-01	6.0E-01
DICHLOROETHYLENE, Cis 1,2-	7.0E+01	5.9E+02	5.9E+02
DICHLOROETHYLENE, Trans 1,2-	1.0E+02	2.6E+02	2.6E+02
DICHLOROPHENOL, 2,4-	3.0E-01	3.0E-01	3.0E-01
DICHLOROPHENOXYACETIC ACID (2,4-D)	7.0E+01	4.0E+01	4.0E+01
DICHLOROPROPANE, 1,2-	5.0E+00	1.0E+01	1.0E+01
DICHLOROPROPENE, 1,3-	4.3E-01	4.6E+00	4.6E+00
DIELDRIN	2.5E-05	2.5E-05	2.5E-05
DIETHYLPHTHALATE	1.5E+00	1.7E+00	1.5E+00
DIMETHYLPHENOL, 2,4-	1.2E+02	1.1E+02	1.1E+02
DIMETHYLPHTHALATE	1.5E+00	1.7E+00	1.5E+00
DINITROBENZENE, 1,3-	3.7E+00	3.0E+01	3.0E+01
DINITROPHENOL, 2,4-	7.3E+01	7.5E+01	7.5E+01
DINITROTOLUENE, 2,4- (2,4-DNT)	3.0E+00	3.0E+00	3.0E+00
DINITROTOLUENE, 2,6- (2,6-DNT)	3.7E+01	6.7E+01	4.4E+01
DIOXANE, 1,4-	6.1E+00	5.0E+04	5.0E+04
DIOXINS (TEQ)	5.0E-09	5.0E-09	5.0E-09
DIURON	6.0E+01	6.0E+01	6.0E+01
ENDOSULFAN	5.6E-02	8.7E-03	8.7E-03
ENDRIN	2.3E-03	2.3E-03	2.3E-03
ETHANOL	5.0E+04	5.0E+04	5.0E+04
ETHYLBENZENE	3.0E+01	3.0E+01	3.0E+01
FLUORANTHENE	8.1E+00	8.0E+00	8.0E+00
FLUORENE	3.9E+00	3.9E+00	3.9E+00
GLYPHOSATE	6.5E+01	6.5E+01	6.5E+01
HEPTACHLOR	9.0E-05	9.0E-05	9.0E-05
HEPTACHLOR EPOXIDE	3.9E-05	3.9E-05	3.9E-05
HEXACHLOROBENZENE	2.4E-04	2.4E-04	2.4E-04
HEXACHLOROBUTADIENE	8.6E-01	4.7E+00	4.7E+00
HEXACHLOROCYCLOHEXANE (gamma) LINDANE	2.0E-02	2.0E-02	2.0E-02
HEXACHLOROETHANE	2.9E+00	2.9E+00	2.9E+00
HEXAZINONE	1.2E+03	5.0E+03	5.0E+03
INDENO(1,2,3-cd)PYRENE	1.8E-02	1.8E-02	1.8E-02
ISOPHORONE	7.1E+01	1.3E+02	1.3E+02
LEAD	1.5E+01	5.6E+00	5.6E+00
MERCURY	4.7E-02	2.5E-02	2.5E-02

TABLE D. ENVIRONMENTAL ACTION LEVELS (EALs)

¹Surface Water Bodies

CHEMICAL PARAMETER	SURFACE WATER ACTION LEVELS		
	² Freshwater (ug/L)	³ Marine (ug/L)	⁴ Estuarine (ug/L)
METHOXYCHLOR	3.0E-02	3.0E-02	3.0E-02
METHYL ETHYL KETONE	7.1E+03	8.4E+03	8.4E+03
METHYL ISOBUTYL KETONE	1.7E+02	1.7E+02	1.7E+02
METHYL MERCURY	3.0E-03	3.0E-03	3.0E-03
METHYL TERT BUTYL ETHER	5.0E+00	1.8E+02	1.8E+02
METHYLENE CHLORIDE	4.8E+00	5.9E+02	5.9E+02
METHYLNAPHTHALENE, 1-	2.1E+00	2.1E+00	2.1E+00
METHYLNAPHTHALENE, 2-	2.1E+00	2.1E+00	2.1E+00
MOLYBDENUM	1.8E+02	2.4E+02	2.4E+02
NAPHTHALENE	1.7E+01	2.1E+01	2.1E+01
NICKEL	5.0E+00	8.3E+00	5.0E+00
NITROBENZENE	3.4E+00	6.0E+01	6.0E+01
NITROGLYCERIN	3.7E+00	1.4E+02	1.4E+02
NITROTOLUENE, 2-	6.2E-02	1.0E+03	1.0E+03
NITROTOLUENE, 3-	1.2E+02	3.8E+02	3.8E+02
NITROTOLUENE, 4-	4.2E+00	1.6E+03	1.6E+03
PENTACHLOROPHENOL	1.0E+00	3.0E+00	3.0E+00
PENTAERYTHRITOLTETRANITRATE (PETN)	6.1E-01	2.2E+04	2.2E+04
PERCHLORATE	2.6E+01	6.0E+02	6.0E+02
PHENANTHRENE	6.3E+00	4.6E+00	4.6E+00
PHENOL	5.0E+00	1.3E+03	1.3E+03
POLYCHLORINATED BIPHENYLS (PCBs)	7.9E-05	7.9E-05	7.9E-05
PROPICONAZOLE	4.2E+01	2.6E+01	2.6E+01
PYRENE	2.0E+00	2.0E+00	2.0E+00
SELENIUM	5.0E+00	7.1E+01	5.0E+00
SILVER	1.0E+00	1.0E+00	1.0E+00
SIMAZINE	4.0E+00	2.0E+00	2.0E+00
STYRENE	1.0E+01	1.1E+01	1.1E+01
TERBACIL	4.7E+02	2.3E+03	2.3E+03
tert-BUTYL ALCOHOL	4.5E+00	1.8E+04	1.8E+04
TETRACHLOROETHANE, 1,1,1,2-	5.2E-01	3.1E+02	3.1E+02
TETRACHLOROETHANE, 1,1,2,2-	6.7E-02	3.5E+00	3.5E+00
TETRACHLOROETHYLENE	2.9E+00	2.9E+00	2.9E+00
TETRACHLOROPHENOL, 2,3,4,6-	1.2E+00	4.0E+00	1.2E+00
TETRANITRO-1,3,5,7-TETRAAZOCYCLOOCTANE (HMX)	3.3E+02	3.3E+02	3.3E+02
THALLIUM	2.0E+00	1.6E+01	1.6E+01
TOLUENE	4.0E+01	4.0E+01	4.0E+01
TOXAPHENE	2.0E-04	2.0E-04	2.0E-04
TPH (gasolines)	1.0E+02	3.7E+03	5.0E+02
TPH (middle distillates)	1.0E+02	6.4E+02	6.4E+02
TPH (residual fuels)	1.0E+02	6.4E+02	6.4E+02
TRICHLOROENZENE, 1,2,4-	2.5E+01	6.5E+01	2.5E+01
TRICHLOROETHANE, 1,1,1-	6.2E+01	6.2E+01	6.2E+01
TRICHLOROETHANE, 1,1,2-	5.0E+00	1.4E+01	1.4E+01
TRICHLOROETHYLENE	5.0E+00	2.6E+01	2.6E+01
TRICHLOROPHENOL, 2,4,5-	6.3E+01	1.1E+01	1.1E+01
TRICHLOROPHENOL, 2,4,6-	1.2E+00	1.2E+00	1.2E+00

TABLE D. ENVIRONMENTAL ACTION LEVELS (EALs)

¹Surface Water Bodies

CHEMICAL PARAMETER	SURFACE WATER ACTION LEVELS		
	² Freshwater (ug/L)	³ Marine (ug/L)	⁴ Estuarine (ug/L)
TRICHLOROPHENOXYACETIC ACID, 2,4,5- (2,4,5-T)	3.7E+02	6.9E+02	6.9E+02
TRICHLOROPHENOXYPROPIONIC ACID, 2,4,5- (2,4,5-TP)	3.0E+01	3.0E+01	3.0E+01
TRICHLOROPROPANE, 1,2,3-	6.0E-01	1.4E+01	1.4E+01
TRICHLOROPROPENE, 1,2,3-	6.1E+01	1.5E+02	1.5E+02
TRIFLURALIN	8.7E+00	2.0E+01	2.0E+01
TRINITROBENZENE, 1,3,5-	3.0E+01	3.0E+01	3.0E+01
TRINITROPHENYLMETHYLNITRAMINE, 2,4,6- (TETRYL)	1.5E+02	1.5E+02	1.5E+02
TRINITROTOLUENE, 2,4,6- (TNT)	2.2E+00	2.0E+01	2.0E+01
VANADIUM	1.9E+01	1.9E+01	1.9E+01
VINYL CHLORIDE	2.0E+00	1.7E+02	1.7E+02
XYLENES	2.0E+01	1.0E+02	1.0E+02
ZINC	2.2E+01	8.6E+01	2.2E+01
Electrical Conductivity (mS/cm, USEPA Method 120.1 MOD)	not applicable	not applicable	not applicable
Sodium Adsorption Ratio	not applicable	not applicable	not applicable
Notes:			
1. Compiled for screening of contaminated groundwater that could discharge to surface water. Check with agency overseeing surface water quality for application to aquatic habitats.			
2. Source of Freshwater EALs: Refer to Appendix 1, Table D-2a for basis. Includes consideration of drinking water action levels.			
3. Source of Marine EALs: Refer to Appendix 1, Table D-2b for basis.			
4. Source of Estuarine EALs: Refer to Appendix 1, Table D-2c for basis.			
Surface water action levels lowest of drinking water goal (freshwater only), chronic aquatic habitat goal, goal to address bioaccumulation in aquatic organisms and subsequent consumption by humans, and general nuisance goal (odors, etc.). Refer to Chapter 2 of text and Appendix 1 for details.			
Estuarine action levels lowest of freshwater and marine action levels.			
Water EALs for ethanol based on gross contamination concerns (see Appendix 1, Chapter 5 and related tables).			
TPH -Total Petroleum Hydrocarbons. TPH EALs must be used in conjunction with EALs for related chemicals (e.g., BTEX, PAHs, oxidizers, etc.). See Section 2.6 and Appendix 1, Chapter 5.			