DoD Vapor Intrusion Handbook
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Considering the Vapor Intrusion Pathway throughout the CERCLA Process

Purpose

This fact sheet was prepared by the Department of Defense (DoD) Tri-Service Environmental Risk Assessment Workgroup (TSERAWG) to provide a roadmap for DoD Project Managers assessing the vapor intrusion (VI) pathway at DoD facilities under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

Introduction

VI is evaluated like any other exposure pathway and should be considered throughout the CERCLA process. Table 1 summarizes the key environmental restoration activities required by the DoD (DERP, 2012) at each step of the CERCLA process and provides examples of VI assessment and/or mitigation activities that may be undertaken to meet CERCLA requirements when evaluating commercial/industrial buildings at DoD facilities. The United States Environmental Protection Agency (U.S. EPA) VI Technical Guide (U.S. EPA, 2015) and the DoD VI Handbook (DoD, 2009) provide guidance for evaluating the VI pathway in residential settings. For both commercial/industrial and residential settings, the approach to developing a VI conceptual site model (CSM) is similar, but the scale of investigation within and around buildings typically is greater in commercial/industrial settings.

Key Challenges in VI Assessment

Experience has shown that there are several common challenges in VI assessment regardless of the type of site under evaluation or stage of regulatory assessment. These are:

- How to address and account for temporal and spatial variability in indoor air concentrations;
- How to address and account for temporal and spatial variability in subsurface concentrations;
- How to identify and quantify background source contributions to indoor air in commercial/industrial settings; background sources commonly result in concentrations that are above conservative risk-based indoor air screening levels for benzene, chloroform, carbon tetrachloride, 1,2-dichloroethene, ethylbenzene, tetrachloroethene, trichloroethene and other contaminants;
- How to identify and quantify potential contributions to indoor air concentrations via preferential pathways, such as utility conduits that intersect vapor sources and are directly connected to a building;

- How to identify and characterize the features of a building that make it susceptible to VI (e.g., foundation construction, air handling/mixing/exchange).

Several emerging methods have been developed to specifically address the above concerns, as detailed in additional DoD TSERAWG fact sheets posted at: https://www.denix.osd.mil/irp/vaporintrusion/**.**

In addition, VI assessment at DoD facilities poses some additional challenges:

- Lack of subsurface VI screening levels appropriate for the large industrial buildings common at DoD facilities;
- Lack of guidance for developing building-specific attenuation factors for use in developing building-specific screening levels;
- Lack of guidance for assessing future potential VI impacts beyond comparison to conservative screening levels based on residential buildings;
- The need to coordinate with Occupational Health personnel prior to sampling indoor air at active sites. Occupational health personnel use different technical approaches and tools to protect human health; and
- Property reuse/redevelopment transactions may be planned (e.g., as part of Base Realignment and Closure [BRAC] development), in which case it may be appropriate to incorporate the VI assessment approach described in ASTM E1527: Phase I – Environmental Site Assessments.

Means of addressing these challenges should be considered at each stage of the CERCLA process, as appropriate, when scoping investigation programs or evaluating response actions.

VI Considerations throughout the CERCLA Process

Table 1 provides a list of the stages of the CERCLA process as applied at Federal facilities, summarizes the key environmental restoration activities required by the DoD (DERP, 2012) at each stage, and describes the types of VI evaluation activities that may be undertaken to meet CERCLA requirements at each stage. The recommended VI evaluation activities at each stage of the CERCLA process are described in greater detail below.

1. Communication with Stakeholders

Communication with stakeholders throughout the CERCLA process helps to build trust. Useful information to relay includes the known nature and extent of contamination, both on site and off site, and the process that will be used to scope additional investigations. The issue of background levels of volatile organic compounds (VOCs) in indoor air should be introduced early. The process of assessing risk under CERCLA should be explained, particularly the difference between screening levels and acceptable risk. It is also important to understand that active DoD installations have an Occupational Health group that defines acceptable levels (and, therefore, the triggers for response actions) for military facilities, which may be different than those established by the U.S. EPA or state regulatory agencies. Relaying

these important concepts early can facilitate stakeholder acceptance of investigation results and interpretations that rely on these concepts.

2. Preliminary Assessment

Preliminary assessment (PA) under CERCLA at Federal facilities involves gathering historical and other available information about site conditions to evaluate whether the site may pose a threat to human health and the environment and whether further investigation is needed (U.S. EPA, 2005a). The PA uses the available information to determine if there has been a release of VOCs into the environment that has contaminated soil and/or groundwater below habitable buildings or areas where habitable buildings will or may be constructed in the future. The PA also involves an assessment whether the VI impact is related to a DoD source. A PA is used to help identify sites that may need immediate or short-term response actions.

It is likely that a PA has been completed at most DoD facilities and was evaluated by U.S. EPA. If U.S. EPA determined that the site did not pose a threat to human health and the environment, the site would have received a "No Further Remedial Action Planned (NFRAP)" designation by U.S. EPA. It is unlikely that the VI pathway would have been explicitly considered in historical PAs; however, the PA would have considered whether releases to soil and/or groundwater occurred, and if so, these data may indicate the need for a follow-up site inspection (SI) (discussed in the next section). If a site has not undergone a PA, detailed guidance for conducting one is provided by U.S. EPA (1991, 2005a).

In general, a PA that includes consideration of the VI pathway should:

- Consider past and current operations involving VOCs and the potential for off-gassing of VOCs from building materials due to historic operations;
- Consider all known or expected actual or potential VOC releases associated with the facility;
- Identify VOC sources at the site, including waste piles, impoundments, landfills, tanks, drums, pipelines, and soil contaminated by spills, leaks, or migration of VOCs;
- Compile waste quantity information, such as waste stream quantities, area estimates, and volumes for each source; and
- Identify major pathways of migration for VOCs (e.g., groundwater, soil, soil gas, preferential pathways, and ambient air).

The VI challenges described above should be considered in evaluating the potential for vapor migration from sources to areas of concern for VI and to identify data gaps. If the PA indicates further investigation is needed, an SI will need to be conducted, as described in the next section. Reporting on a PA often is combined with results from an SI.

3. Site Inspection

The SI phase under CERCLA builds upon information collected during a PA and generally involves limited subsurface sampling (groundwater, soil, soil gas) and, potentially, air sampling at the site to determine

what hazardous substances are present and whether they are being released to the environment and are a potential threat to human health or the environment. It is likely that an SI also has been completed at most DoD facilities, although the VI pathway may not have been evaluated.

For VI assessment at DoD facilities, the focus of the SI generally is on subsurface (groundwater and soil gas) sampling to identify and delineate subsurface vapor sources to determine the potential for VI to occur in nearby existing occupied, potentially occupied or future planned buildings. If groundwater or soil gas data are available from a prior SI, initial evaluation of the VI pathway can be accomplished by comparing measured contaminant concentrations in groundwater and/or soil gas to U.S. EPA's default Vapor Intrusion Screening Level (VISLs) or VISLs derived using commercial / industrial building attenuation factors (DON, 2015) for large buildings as they become available. Current U.S. EPA VISLs are based on attenuation factors developed from a database of primarily residential buildings and may not represent attenuation into commercial / industrial buildings.

If soil gas data are not available, consider using bulk soil data, if available, to identify VOC vapor sources and guide further sampling. Although there is uncertainty in using bulk soil data for VI assessment (U.S. EPA, 2014, 2015), bulk soil in which VOCs are detected using standard soil sampling and analysis methods likely indicate the presence of VOC vapor sources, because bulk soil detection limits are high compared to the soil concentrations that will result in soil gas concentrations that will exceed U.S. EPA VISLs (U.S. EPA, 2019. While bulk soil data may be used to identify potential sources, bulk soil data cannot be used to screen out VI concerns due to the potential sampling bias and spatial variability often associated with soil sampling results.

It may be necessary to collect additional groundwater or soil gas data to delineate the subsurface contamination and perform the screening. Groundwater plumes evaluated using non-potable criteria (higher than drinking water standards) may need additional delineation to identify areas of potential VI concern. Additional delineation may also be considered for contaminants with VISLs lower than drinking water standards, although there is no empirical evidence that indicates VI impacts have been associated with groundwater concentrations less than drinking water standards. If indoor air sampling is considered necessary at this stage to determine if VI is contributing to indoor air concentrations, coordination with Occupational Health personnel is recommended prior to sampling indoor air at active sites. Note that background sources of VOCs are common in commercial/industrial settings and, for this reason, indoor air analyses should be focused on contaminants of potential concern (COPCs) associated with a CERCLA release.

The SI data are used to determine the need for further action; i.e., NFRAP, removal action, or remedial investigation (RI). If the data collected in the PA and SI phases suggest concerns due to VI are possible, a CERCLA removal action may be considered or further investigation may be warranted. If the site is not already being investigated under CERCLA, U.S EPA may score it using the Hazard Ranking System (HRS), which was revised in 2017 to include the VI pathway by adding a "subsurface intrusion" component, which includes both VI and direct intrusion of contaminated groundwater into structures.

4. Remedial Investigation

The RI of the VI pathway at DoD facilities involves conducting field investigations to collect the data needed to develop a VI CSM, including determining the nature and extent of VOC contamination in the subsurface, characterizing the VI pathways between the delineated VOC sources (areas of subsurface VOC contamination that exceed VISLs) and nearby existing buildings or planned construction, evaluating the potential impacts of preferential pathways, and assessing the risk to human health via the VI pathway. Figure 1 presents a generalized flow chart for evaluating the VI pathway during the RI process.

At any stage of an RI, it is important to identify appropriate VI investigation data quality objectives (DQOs) for the site. DoD TSERAWG Fact Sheet No. 007 "Matrix for Selecting Vapor Intrusion Investigation Technologies" provides a list of typical VI investigation objectives that can be used to develop site-specific DQOs and describes the available technologies that can provide data to address the objectives. VI investigation objectives often follow a "bottom-up" approach, from characterization of subsurface sources, through evaluation of vadose zone vapor migration pathways, to investigation of a building's sub-slab region and interior. However, assessment of the VI pathway can begin at any point in the process, depending on site-specific conditions and Remedial Project Manager (RPM) or lead agency preferences. If property transactions are planned (e.g., as part of BRAC development), it may be appropriate to consider the VI assessment approach described in ASTM E1527: Phase I – Environmental Site Assessments.

Specific considerations for VI investigations at DoD facilities are described below.

- **Identify and delineate potential vapor sources:** As described in the DoD Manual (2012), the source of contamination should be located on DoD, BRAC, or formerly used defense sites (FUDS) property.
- **Characterize near source vapor concentrations:** Focus the investigation on COPCs for the VI pathway. Near source vapor concentrations may be estimated from groundwater concentrations in samples collected from wells screened across the water table or by sampling soil gas near known or suspected groundwater or soil sources. Sampling results that show exceedances of U.S. EPA VISLs (or alternative VISLs, as appropriate) indicate areas that require additional investigation of the VI pathway.
- **Identify vapor migration pathways in the subsurface:** Identify characteristics of the vadose zone that control vapor migration pathways, which may involve soil gas sampling in the vadose zone characterizing heterogeneities in soil properties, as well as determining presence and potential impact of subsurface utilities (sewer lines, telephone or electrical tunnels, drains, etc.) (e.g., by sampling sewer gas) that intersect VOC sources and may connect sources to buildings.
- **Prioritize areas of potential VI risk:** The available subsurface data and preliminary building information can be used to screen and prioritize areas and/or buildings for further investigation. The Navy's Quantitative Decision Framework (QDF) (Navy, 2015) can be used as a tool for screening and prioritizing DoD buildings for VI assessment. In addition, the DoD TSERAWG Fact Sheet No. 007 "Matrix for Selecting Vapor Intrusion Investigation Technologies" provides Information on VI sampling technologies.

- **Characterize building conditions that influence VI:** Characterize building features that may promote VI (e.g., large cracks and unsealed utility penetrations). Document heating, ventilation, and air conditioning operations in buildings and consider monitoring pressure differentials across the building envelope and foundation to determine the building's susceptibility to VI. Depressurized buildings promote VI. Pressurized buildings resist VI. In cases where subslab source concentrations are exceedingly high (> 10^5 µg/m^3), diffusion across the slab may contribute to the presence of VOCs in indoor air despite positive pressurization of the building. Specialized techniques such as building pressure cycling (BPC) (DoD TSERAWG Fact Sheet No. 4) and high volume subslab sampling (HVS) (DoD TSERAWG Fact Sheet No. 3) also can be used to assess building susceptibility to VI. Susceptibility may also be assessed through the use of tracers and surrogates (DoD TSERAWG Fact Sheet No. 5). These activities may be conducted prior to or after indoor air sampling.
- **Conduct indoor air sampling, if appropriate:** If indoor air sampling is considered necessary to determine if VI is contributing to indoor air concentrations, coordination with Occupational Health personnel is recommended prior to sampling indoor air at active sites. The indoor air sampling methods vary according to the objectives of the sampling, and consideration should be given to methods that either characterize or manage variability. Time-integrated methods of sampling (e.g., via evacuated canisters) generally are required for assessing potential exposures and health risks). It is important to recognize that background sources of VOCs are common in commercial/industrial settings and can contribute to indoor air VOC concentrations. For this reason, indoor air analyses should be focused on the COPCs associated with a CERCLA release. Methods for assessing the influence of background sources may also be considered, where practicable (e.g., use of portable air monitoring equipment such as a photoionization detector [PID] or a HAPSITE) to pinpoint potential sources or BPC to quantify background emissions). Concurrent collection of subslab samples and cross-slab differential pressure monitoring, if practicable, assists with data interpretation.
- **Conduct baseline risk assessment:** DoD TSERAWG Fact Sheet No. 9 provides guidance for conducting a VI risk assessment under CERCLA (in progress). The risk assessment results will be used to determine the need for VI pathway mitigation and subsurface remediation. If there are exceedances of either short-term or long-term targets, DoD project managers should collaborate with Occupational Health personnel since they are responsible for the health of all occupants in DoD-controlled non-residential buildings regardless of the source.

5. Feasibility Study

The Feasibility Study (FS) uses the information collected in the RI to develop, screen, and conduct a detailed evaluation of subsurface remedial alternatives to address potential risks arising from the VI pathway. Any remediation technology that aims to reduce subsurface concentrations to levels below site-specific cleanup levels may be considered. VI mitigation systems may be installed as interim measures or removal actions in existing buildings to protect human health while remedial action is ongoing. However, a determination that interim commercial/industrial building mitigation measures are needed at active DoD facilities requires consultation with Occupational Health personnel and the building engineers, as well as approval of the Commanding Officer.

If the RI data support development of site-specific groundwater-to-indoor air and soil gas-to-indoor air (and, potentially, sewer gas-to-indoor air) attenuation factors, the FS may propose site-specific subsurface (and, potentially, utility conduit vapor) cleanup levels protective of the VI pathway based on the site-specific attenuation factors and exposure parameters.

6. Record of Decision

The Record of Decision (ROD) regarding the VI pathway at active DoD facilities primarily identifies cleanup goals and remedial actions for subsurface VI sources. Both current and future exposures should be addressed. Building VI mitigation measures may be included as temporary measures to intercept the pathway until sources are addressed, but their implementation requires consultation with Occupational Health personnel and the building engineers, as well as approval of the Commanding Officer. Generally, the ROD should not specify cleanup goals for indoor air in buildings at active facilities, as Occupational Health personnel is responsible for the health and safety of workers. Institutional controls (ICs) (i.e., land use controls [LUCs]) may be included to preclude new construction in areas that may pose a VI risk or to require VI investigation or mitigation if new buildings are constructed.

7. Remedial Design / Remedial Action

The remedial design (RD) and remedial action (RA) stages, designated by DoD as Remedial Action Construction and Remedial Action Operation (DERP, 2012), include development of design criteria for VI remedial actions to address subsurface contamination that may pose unacceptable VI risks as well as performance criteria to demonstrate that the selected remedy is performing as designed. It is critical that performance criteria/monitoring and exit strategies be developed during this stage of the CERCLA process. Operations and maintenance (O&M) options specific to reducing potential VI risks due to subsurface contamination should be specified during this phase, as should any ICs.

If interim building mitigation measures are a component of the site remedy, performance criteria based on physical measures, such as vacuum or pressure differential, or on the mass flux of captured soil vapor offer a more cost-effective means of ensuring adequate performance of building mitigation systems than do criteria based on chemical concentrations in indoor air. As for remedial actions targeting subsurface vapor sources, it is critical to define termination criteria for active building mitigation systems.

8. Remedial Action Construction Complete

The Remedial Action Construction Complete milestone is designated by DoD as the Remedy-in-Place (RIP) milestone (DERP, 2012). This is achieved when the remedial action construction is complete, is functional, is operating as planned in the RD, and is expected to meet the remedial action objectives (RAOs). For the VI pathway, this milestone documents completion of construction activities for the engineered components of VI response actions (including interim building mitigation systems), documents that the remedy is operating properly and successfully, as defined by the remedy

performance criteria, and demonstrates progress towards achieving the site subsurface cleanup levels protective of the VI pathway.

9. Long-Term Monitoring

Long-term monitoring (LTM) typically is required to ensure long-term protectiveness of the remedy when RAOs do not allow unrestricted use of the property. Periodic monitoring reports for remedies targeting subsurface contamination that may pose unacceptable VI risks typically include monitoring results of groundwater and soil gas sampling in vapor source areas, as well as monitoring of performance criteria for engineered systems designed to remediate subsurface contamination and/or interim building mitigation systems designed to interrupt the VI pathway while subsurface remediation is ongoing.

10. Five-Year Reviews

The data contained in periodic monitoring reports and information collected during site visits conducted for the five-year review are used to assess the protectiveness of a VI remedy at DoD Superfund sites. Information on the approach can be found in U.S. EPA's Assessing Protectiveness at Sites for Vapor Intrusion: Supplement to the Comprehensive Five-Year Review Guidance (U.S. EPA, 2012). This guidance provides a detailed overview of factors to consider when evaluating the technical assessment questions for the five-year review. The guidance also provides recommendations for assessing protectiveness at sites where a VI remedy has not been implemented, the VI pathway was never adequately characterized, or changes in site conditions since the last five-year review have potentially led to a complete VI pathway (U.S. EPA, 2012).

The VI pathway should be further evaluated if it was not considered at the time site-related decision documents were issued or if new site information (discovered since the decision documents were issued) suggests that VI is now a potential pathway of concern at a site. The five-year review site team should consider whether there are adequate, appropriate data to evaluate the pathway prior to commencing the five-year review. Existing data relevant to the VI pathway (e.g., sample results including VOCs, hydrogeologic information that informs the likelihood of VI migration in the vadose zone, building construction details, planned building construction, etc.) collected as part of the SI, RI, FS and remedy performance evaluations should be reviewed for this purpose. DQOs to develop the needed data for a five-year review should be considered (see discussion of VI pathway investigation objectives in the section on RIs). If inadequate data are available, the five-year review document can recommend gathering appropriate data relevant to potential VI and defer a protectiveness statement until the appropriate data are collected and evaluated.

If decision documents identified the VI pathway as a potential risk to human health at a site, the data collected as part of the remedy performance evaluation should help assess whether the portion of the remedy that was designed to address the VI pathway is operating as intended and is still ensuring protectiveness of human health of occupants in existing buildings and/or will protect human health of occupants in planned future building construction.

11. Site Closeout

Site Closeout (SC) under CERCLA is achieved when all site cleanup has been completed and all cleanup goals have been met. For sites where remedies were selected to address VI risks, SC generally requires that subsurface contamination has been remediated to the extent that VI risks, if any, are acceptable even in the absence of temporary building mitigation systems. A Remedial Action Completion Report (RACR) (DERP, 2012) is prepared to document DoD has met the RAOs at a specific site, group of sites, or an entire installation, BRAC location, or FUDS property, and documents that the site has either achieved unlimited use and unrestricted exposure or that the remedy remains protective while RAOs have been achieved. The RACR provides the basis for full or partial deletion from the National Priorities List.

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Table 1: Summary of key environmental restoration activities required by the DoD and recommended VI assessment activities at each step of the CERCLA process

CERCLA Process for Federal Facilities	DoD Environmental Restoration Phases		VI Assessment Activities
Preliminary Assessment (PA)	Removal Actions may occur at any time	Review existing information to determine if a hazardous substance or pollutant or contaminant release requires additional investigation or action. Evaluate relative risks according to "Relative Risk Site Evaluation (RRSE) Primer" (DoD, 1997), considering contaminants hazards, migration pathways, and potential receptors. Communicate with stakeholders.	Assess existing data and assemble preliminary CSM. Identify the following CSM elements: subsurface sources (groundwater and soil) with concentrations ≥ screening levels; current and future planned buildings near subsurface sources; utility conduits potentially intersecting known sources; utility connections to occupied or occupiable buildings; and data gaps. Evaluate VI potential and prioritize buildings for inspection, if needed. Communicate with stakeholders.
Site Inspection (SI)		Conduct an on-site and off-site reconnaissance, as needed, which may involve sampling environmental media and collecting and analyzing other data to determine the need for further action or investigation. Refine the RRSE and prioritize areas of concern for additional investigation or action, as needed.	Conduct a limited investigation of groundwater and/or soil gas to determine whether hazardous volatile substances are present and whether they pose a potential threat to human health or the environment. Compare groundwater and/or soil gas concentrations to default screening levels (or alternative large commercial/industrial building screening levels as they become available). Communicate with stakeholders.
No Further Remedial Action Planned (NFRAP), National Priorities Listing (NPL) or Non-NPL Superfund Alternative Approach (SAA)	Milestone	The data collected in the PA and SI are used to determine the need for further action or investigation. (i.e., no further action, removal action or remedial investigation/ feasibility study). If the site is not already being investigated under CERCLA, removal action may be considered or the PA/SI results may be scored using the Hazard Ranking System (HRS).	If the SI indicates concerns due to VI are possible, either removal action or further investigation will be required. US EPA added a subsurface intrusion component to the HRS via a rulemaking action that took effect on May 22, 2017. This component of the HRS allows EPA to consider human exposures to contaminants that enter occupied structures through subsurface vapor intrusion when evaluating a site for placement on the NPL.
Remedial Investigation (RI)	Interim Remedial Actions may occur at any time	Conduct field investigations to characterize site conditions, determine the nature and extent of the contamination, and evaluate risks to human health and the environment posed by the site conditions by conducting a baseline ecological and human health risk assessment. Data quality objectives should consider current and reasonably anticipated future land uses and the remedial alternatives that will address the known or potential chemical hazards.	Collect data to fully delineate VI sources, characterize the VI pathway between the identified sources (areas of subsurface VOC contamination that exceed VISLs), evaluate the potential impacts of preferential pathways, and assess risks to potential receptors (occupants of current or future buildings) and the environment. Prioritize areas of potential VI risk. Indoor air sampling generally is needed to complete the baseline human health risk assessment where buildings are present and requires the approval of the Commanding Officer. Communicate with stakeholders.
Feasibility Study (FS)		If site conditions present an unacceptable risk based on the RI risk assessment, identify remedial actions objectives (RAOs) and develop, screen, and evaluate remedial alternatives. Assess the remedial alternatives in detail according to the nine	For the FS phase, the data collected in the RI are used to develop, screen, and conduct a detailed evaluation of subsurface remedial and/or mitigation actions to address documented or potential risks arising from the VI pathway.

Table 1 (continued): Summary of key environmental restoration activities required by the DoD and recommended VI assessment activities at each step of the CERCLA process

CERCLA Process for Federal Facilities	DoD Environmental Restoration Phases		VI Assessment Activities
		criteria found in the NCP (300.430€(9)(iii)). Identify the preferred alternative.	
Record of Decision (ROD)	Milestone	Prepare the proposed plan: summarize the key factors in the RI/FS that led to identifying the preferred alternative. Prepare the decision document (DD): Summarize the results of the risk assessment. Describe the remedial alternatives evaluated in the detailed analysis of remedial alternatives and discuss the rationale that supports the preferred alternative. Describe the proposed RAOs and remediation goals (RGs). Summarize any formal comments received from any supporting agencies.	The ROD primarily identifies cleanup goals and remedial actions for subsurface VI sources to address current and future exposures. Building VI mitigation measures may be included as temporary measures to intercept the pathway until sources are addressed, but their implementation requires the approval of the Commanding Officer. The ROD should not specify cleanup goals for indoor air in buildings at active facilities, as Occupational Health is responsible for the health and safety of workers. Institutional Controls (ICs) may be included to preclude new construction or require VI investigation or mitigation if new buildings are constructed in areas that may pose a VI risk.
Remedial Design (RD) Remedial Action (RA)	Cleanup	Remedial Action Construction: Prepare a RA WP for construction and implementation of the selected remedial action(s). Include a Land Use Control (LUC) implementation plan if LUCs are a required element of the selected remedial action. Remedial Action Operation: The remedial action, including any LUCs, are operated, maintained, and monitored until RAOs are achieved.	The RD and RA stages specify design and performance criteria for VI remedial actions that address subsurface contamination that poses or may pose VI risks. The remedy and ICs included as part of the selected remedy are implemented and maintained in the RA stage. Performance and termination criteria also should be defined for any building mitigation measures that are a component of the site remedy.
Remedial Action Construction Completion	Milestone	Remedy in Place (RIP): The RIP milestone is achieved when the remedial action construction is complete, is functional, is operating as planned in the RD, and is expected to meet the RAOs.	VI mitigation or other remedial measures are in place and operating according to their design.
Long-Term Monitoring (LTM)	Cleanup	Long-term monitoring may be required to ensure long-term protectiveness of the remedy when remedial action objectives do not allow unrestricted use of the property. Monitoring results and performance criteria are documented in periodic monitoring reports.	LTM is required for remedies targeting subsurface contamination that poses or may pose VI risks. This typically includes monitoring of groundwater and soil gas in vapor source areas, along with monitoring of performance criteria for engineered systems designed to remediate subsurface contamination and/or interim building mitigation systems.
Five Year Review (FYR)		Evaluate the implementation and performance of a remedy to determine if the remedy continues to meet the requirements specified in the DD and remains protective of human health and the environment.	The FYR review verifies the effectiveness of remedies implemented to address current or future potential VI risks. See U.S. EPA's 2012 Supplement to the Comprehensive Five-Year Review Guidance: Assessing Protectiveness at Sites for Vapor Intrusion.

Table 1 (continued): Summary of key environmental restoration activities required by the DoD and recommended VI assessment activities at each step of the CERCLA process

CERCLA Process for Federal Facilities	DoD Environmental Restoration Phases		VI Assessment Activities
Site Closeout (SC)	Milestone	A Remedial Action Completion Report (RACR) is prepared that documents the achievement of RAOs, cleanup goals, and remedy protectiveness. The RACR provides the basis for full or partial deletion from the NPL as applicable.	SC is achieved when all site cleanup has been completed, all cleanup goals have been met, and interim building mitigation systems are no longer needed.

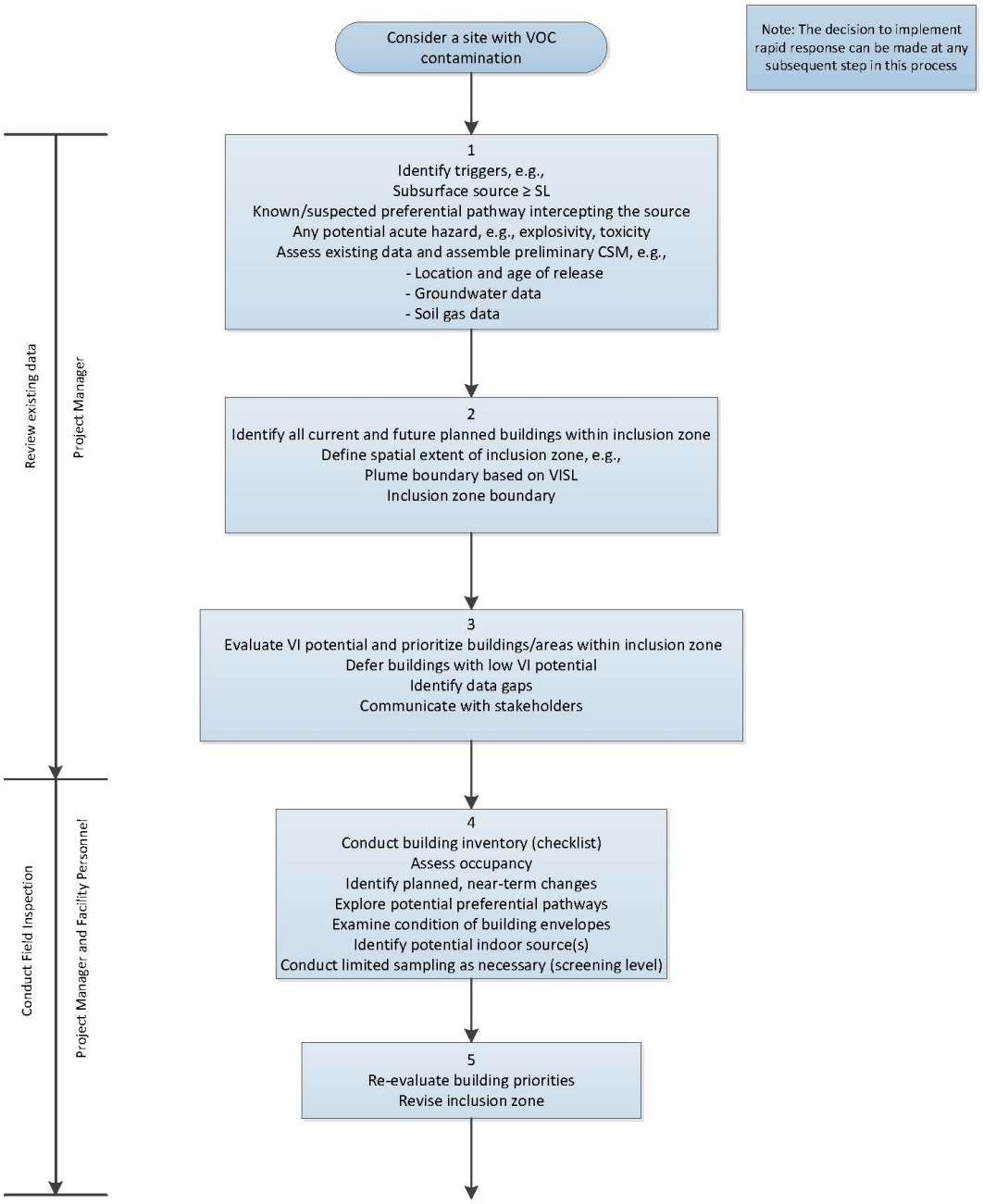

Figure 1: Generalized flow chart for VI pathway investigations during remedial investigations at DoD facilities (Source: DoD)

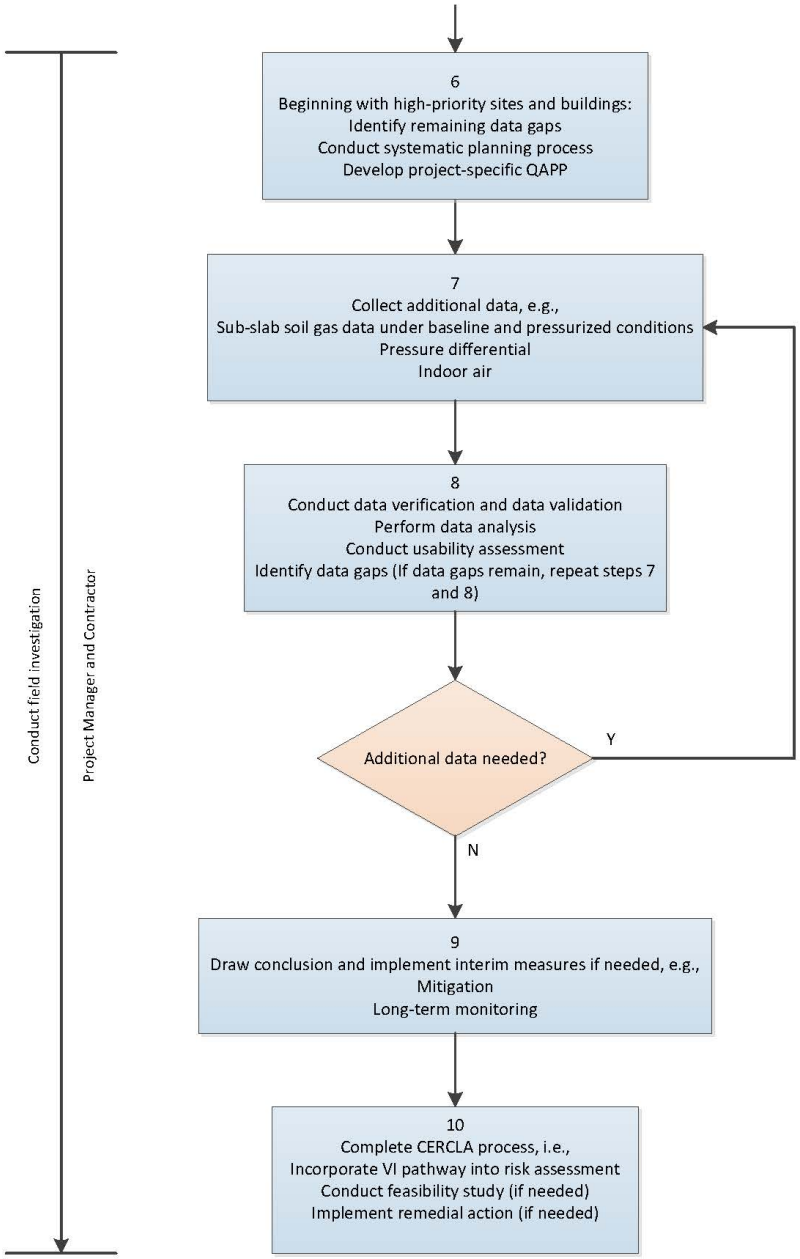

Figure 1 (continued): Generalized flow chart for VI pathway investigations during remedial investigations at DoD facilities (Source: DoD)