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Attorneys for Petitioner
Varian Medical Systems, Inc.

BEFORE THE STATE WATER RESOURCES CONTROL BOARD

In the Matter of the Petition for Review by Hewlett-Packard Company and Varian Medical Systems, Inc. of the San Francisco Bay Regional Water Quality Control Board Letter dated January 23, 2014 Pursuant to Water Code Section 13267	**PETITION FOR REVIEW AND REQUEST FOR HEARING**

Hewlett-Packard Company and Varian Medical Systems, Inc. ("Petitioners") hereby file this Petition for Review and Request for a Hearing by the State Water Resources Control Board ("State Board") of the letter from the San Francisco Bay Regional Water Quality Control Board (the "Regional Board") dated January 23, 2014 issued pursuant to Water Code Section 13267 and pertaining to required indoor air testing in the vicinity of 640 Page Mill Road, Palo Alto, Santa Clara County (the "Order"). This Petition for Review is filed pursuant to the Water Code § 13320 and 23 CCR §§ 2050 et seq. A copy of the Order is attached hereto as Exhibit A.

Notwithstanding this Petition, Petitioners are moving forward with and implementing the work set forth in the *Addendum to the February 17, 2012 Revised Work Plan for Indoor Air Testing.* Petitioners have filed this Petition as a protective filing to preserve their rights and to allow for a forum where the impacts and the basis for the new approach to vapor intrusion investigations dictated to the Regional Board by EPA Region 9 may be discussed and addressed. Petitioners are concerned with procedural and other defects relating to the Order, particularly the Regional Board's direction that Petitioner's approved Work Plan be revised to incorporate certain requirements of a December 3, 2013 letter from EPA Region 9 to the Regional Board purporting to communicate new requirements for vapor intrusion sampling in the South Bay (the "EPA Letter"). The required revision to the approved Work Plan and incorporation of the EPA Letter requirements is particularly troubling given that EPA Region 9 failed to follow any formal procedure in establishing the requirements and these requirements may have far reaching impacts and create significant uncertainty, not only for Petitioners, but also for the residents and business owners in Palo Alto who will be subject to the disruption inherent in their implementation.

Petitioners acknowledge the significant efforts of the Regional Board over the period of more than twenty-five years in which Petitioners and the Regional Board have worked together to investigate and address conditions in the California-Olive-Emerson ("COE") Study Area. Petitioners acknowledge that the Regional Board received from EPA Region 9 multiple written communications directing the Regional Board on how the ongoing vapor intrusion study should be modified and how previous conclusions should be reversed. Petitioners recognize that the Regional Board seeks to work closely with and to cooperate with EPA Region 9. However, significant procedural issues and practical uncertainties are triggered when the Regional Board reverses approvals it has previously issued and does not apply its own published sampling procedures, standards, screening levels, and action levels or those published by U.S. EPA, but, rather selectively applies to nine sites in the South Bay Area new "requirements" communicated by letter from EPA Region 9 to the Regional Board.

Petitioners seek to resolve this matter through discussions with the Regional Water Board and EPA Region 9 regarding appropriate next steps in the ongoing indoor air testing. Because Petitioners are confident that this matter can be resolved in a timely manner, Petitioners request the State Board to hold this Petition in abeyance pursuant to 23 CCR § 2050.5.

I. <u>Name and Address of Petitioners</u>

Petitioners are:

Hewlett-Packard Company, 3000 Hanover Street, Palo Alto, California 94304 who may be contacted through its counsel of record:

Christopher M. Roe
Fox Rothschild LLP
747 Constitution Drive, Suite 100
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croe@foxrothschild.com

With a copy to:

Cristina Armstrong
Fox Rothschild LLP
235 Pine Street, Suite 1500
San Francisco, CA 94104-2734
415-364-5546
carmstrong@foxrothschild.com, and

Varian Medical Systems, Inc., 3100 Hansen Way, Palo Alto, California 94304, who may be contacted through its counsel of record:

Gordon C. Atkinson
Kathleen H. Goodhart
Cooley LLP
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San Francisco, CA 94111-3580
415-693-2000
atkinsongc@cooley.com
goodhartkh@cooley.com

II. The Regional Board Action for Which This Petition for Review is Sought

The Regional Board action for which this Petition for Review is filed is the issuance of the Order.

III. Date the Regional Board Acted

The date of the Regional Board's action Petitioners request the State Board to review occurred on January 23, 2014.

IV. Statement of the Reasons the Action was Inappropriate and Improper

The issuance of the Order was beyond the authority of the Regional Board and inappropriate and improper as explained below.

Background:

Petitioners have been cooperating with the Regional Board and with EPA Region 9 since the early 1980s to investigate and implement response actions at and near the 640 Page Mill Road and 601 California Avenue sites. These sites and the area downgradient are known as the California-Olive-Emerson Study Area (the "COE Study Area"). In September 2010, the Regional Board and EPA Region 9 issued a report that concluded that further study was needed in the COE Study Area of the potential for vapors, primarily trichloroethylene ("TCE"), to migrate from affected groundwater into buildings.

In response, Petitioners submitted to the Regional Board a Work Plan for Indoor Air Testing – COE Study Area for 640 Page Mill Road and 601 California Avenue, which was approved by the Regional Board by letter dated March 12, 2012 (the "Work Plan"). The Regional Board approval letter is attached as Exhibit B. Between April 2012 and August 2012, Petitioners implemented the indoor air sampling program set forth in the Work Plan. Petitioners sampled the indoor air of 12 single-family and five multi-family buildings. The samples were collected and analyzed in accordance with EPA and Regional Board requirements and all results indicated **no detection** in the living spaces of TCE or other constituents in the groundwater underlying the properties. These results were communicated in writing by EPA Region 9 to the residents of the single-family homes by letters dated December 13, 2012. These letters stated:

> Trichloroethylene (TCE) was not detected in your home. … The indoor air sampling results from the 12 residences sampled in the area, including your home, indicate that vapor intrusion from subsurface groundwater contamination does not appear to be occurring. ***Therefore, no additional air sampling is recommended at your home.***

An example EPA Region 9 letter to residents is attached as Exhibit C (redacted to protect the name and address of the homeowner).

In September 2013, Petitioners were informed that EPA Region 9 was considering reversing some of its conclusions regarding the COE indoor air study. In response Petitioners wrote to the Regional Board and EPA Region 9 and by letter dated October 23, 2013, expressed their concern regarding the proposed reversal of conclusions previously made and communicated to residents by EPA Region 9 and the intention of the agencies to impose a new approach and new set of standards and requirements on the on-going COE vapor intrusion investigation. A copy of Petitioners' letter to the Regional Board and EPA Region 9 is attached as Exhibit D. Petitioners requested a meeting with management of the agencies to discuss their concerns. A meeting was held on October 30, 2013 among representative of Petitioners and EPA Region 9, however, the Regional Board was unable to attend. At the meeting, EPA Region 9 expressed its views on its new approach to vapor intrusion investigations in the South Bay area. EPA Region 9 also indicated that it expected EPA headquarters to publish, before the end of the 2013 calendar year, new TCE short-term action levels. However, as of the date of filing this Petition, EPA headquarters has not issued any TCE short-term action levels. It is unclear if the short-term action levels in the letter from EPA Region 9 will be consistent with any short-term action levels that may be published by EPA headquarters.

In an effort to address the concerns of EPA Region 9, and in response to requests from the Regional Board and EPA Region 9, in November 2013, Petitioners submitted to the Regional Board a proposed Addendum to Petitioners' previously approved Work Plan. By memorandum dated November 26, 2013, EPA Region 9 communicated to the Regional Board extensive comments on Petitioners' proposed Addendum. A copy of the EPA Region 9 November 26, 2013 memorandum is attached as Exhibit E. The EPA Region 9 comments made clear that EPA Region 9 was imposing on the Regional Board a whole new set of requirements that were not based on U.S. EPA published regulations, standards or guidance and which were not consistent with Water Board published regulations, standards and guidance.

Then, by letter dated December 3, 2013, EPA Region 9 communicated to the Regional Board "EPA Region 9 Guidelines and Supplemental Information Needed for Vapor Intrusion Evaluations at the South Bay National Priorities List (NPL) Sites" ("EPA Letter"). A copy of the EPA Letter is attached as Exhibit F. Following the Regional Board's receipt of the EPA Letter, the Regional Board informed Petitioners that it intended to impose the "guidelines" in the EPA Letter to Petitioners' ongoing study of indoor air in the COE Study Area. Stated shortly, Petitioners were informed by the Regional Board that they were required to modify their approved Work Plan to include the new "guidelines" contained in the EPA Letter.

The "guidelines" set forth in the EPA Letter have not been developed pursuant to a formal rulemaking process or even adopted as official guidance by the Region, or (more importantly) issued by or adopted by US EPA headquarters. In fact, the guidelines are potentially inconsistent with federal draft guidance in a number of ways. Specifically, the short-term response action levels that are included in the EPA Letter are not included in the draft "OSWER Final Guidance for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Sources to Indoor Air", which was issued for comment by the U.S. EPA Office of Solid Waste and Emergency Response in April 2013, a copy of which is attached as Exhibit G. This is particularly noteworthy since the EPA Letter cites a September 2011 EPA IRIS study as the basis for the short-term response action levels, but the IRIS study was published more than a year and a half before the draft EPA Office of Solid Waste draft guidance was issued for public comment.

Petitioners value their relationship with the Regional Board and EPA Region 9 and as stated previously, Petitioners will implement the work set forth in the Addendum to the February 17, 2012 Revised Work Plan for Indoor Air Testing. However, Petitioners believe that there are significant procedural deficiencies in the Regional Board's incorporation of requirements of the EPA Letter into the Order and imposition of EPA Region 9's "guidelines" to the COE Study Area, and are filing this Petition to allow for a forum to discuss these issues. The imposition of new "guidelines," which have not been subject to public notice or comment or any formal vetting process, and which supplant established and published sampling procedures, standards, screening levels, and action levels of the Regional Board and U.S. EPA, have resulted and are likely to continue to result in conflicting and confusing communications to Petitioners, as well as residents and property owners in the South Bay Area. The implementation of these uncertain "guidelines" may result in duplicative and unwarranted sampling that will be disruptive to families and businesses in Palo Alto. Petitioners also note that the new "guidelines" are being applied by the Regional Board selectively to only nine sites in the South Bay Area.

Therefore, the Regional Board has acted inappropriately and improperly as follows:

A. The Regional Board incorporated certain of the EPA Letter "guidelines" into the Water Board's request for a revision of the Work Plan and into the Order. Those "guidelines" have not been subject to public notice or comment and otherwise fail to comply with the essential requirements of administrative law. Such action by the Regional Board is contrary to law, beyond the Regional Board's authority, an abuse of discretion and without support in the administrative record.

B. By incorporating certain of the EPA Letter guidelines into the Water Board's request for a revision of the approved Work Plan and into the Order, the Regional Board applied EPA Region 9's guidelines in contravention of its own published standards and criteria, e.g., the San Francisco Bay Regional Water Quality Control Board 2013 Tier ESLs. Such action is contrary to law, beyond the Regional Board's authority, an abuse of discretion and without support in the administrative record.

C. The Regional Board incorporated certain of the EPA Letter "guidelines" into the Water Board's request for a revision of the approved Work Plan and into Order, which are potentially inconsistent with published draft Guidance from the U.S. EPA Office of Solid Waste, and which are subject to change once the U.S. EPA Office of Solid Waste Guidance becomes final. Such action by the Regional Board is contrary to law, beyond the Water Board's authority, an abuse of discretion and without support in the administrative record.

D. The Regional Board reversed its March 12, 2012 approval of Petitioners' Work Plan for indoor air testing in the COE Study Area without a basis in the law or support in the administrative record, which is beyond the Regional Board's authority, an abuse of discretion, and arbitrary and capricious. Specifically, more than 18 months after approving Petitioners' Work Plan for a vapor intrusion study in the COE Study Area, while the study was well underway, without any changes in the site remedial decision documents, regulations, published standards or other legal requirements, the Regional Board informed Petitioners that the

Work Plan required significant changes before Petitioners could continue to implement the study.

E. The Regional Board specified the design, location, type of construction and/or particular manner in which compliance was to be accomplished by Petitioners in their implementation of the COE indoor air study, which is expressly prohibited by Water Code §13360. Under Water Code § 13360, a Regional Board order may not specify the design, location, type of construction, or particular manner in which compliance with an order may be accomplished; although the Regional Board may suggest methods for compliance, the recipient of the order must be allowed to comply in any lawful manner. In the instant matter, the Regional Board specified the exact properties to be sampled (location); the location for placement of the sampling devices (e.g., crawl spaces); the particular manner in which samples are to be collected (e.g., HVAC off for at least 36 hours prior to and during the sampling); and the location of the study boundaries. Petitioners must be allowed to comply in any lawful manner.

F. The Regional Board included in the Order a requirement to sample in residential crawl spaces, which is in conflict with the published screening levels of the San Francisco Bay Regional Water Quality Control Board, which establish screening levels for: 1) groundwater; 2) soil; 3) soil gas and 4) indoor air. No screening level has been established for crawl space air and as such it is inappropriate for the Regional Board to require the collection of data for which there is no basis to determine if further action is warranted. Such action by the Regional Board is contrary to law, beyond the Regional Board's authority, an abuse of discretion and without support in the administrative record.

G. The Regional Board included in the Order a recommendation to conduct two closely spaced sampling events one or two weeks apart. The Regional Board may approve or disapprove of a work plan but it is beyond the authority of the Regional Board to include a recommendation that substantially modifies the substance of an approved work plan. Such action by the Regional Board is contrary to law, beyond the Regional Board's authority, an abuse of discretion and without support in the administrative record.

H. The Order was issued pursuant to Water Code Section 13267, which allows the Regional Board to require the submission of technical or monitoring reports. However, the Order imposes remedial obligations and remedial performance standards on Petitioners. Water Code Section 13267 does not authorize the Regional Board to impose such obligations. The remedial obligations and remedial performance standards have been imposed on Petitioners without the procedural and factual basis that would be required by California Water Code Section 13304 for the issuance of a Cleanup and Abatement Order. Such action by the Regional Board is contrary to law, beyond the Regional Board's authority, an abuse of discretion and without support in the administrative record.

I. The Regional Board failed to base the Order on material facts supported by substantial, relevant evidence in the record. For example, and without limitation, the Order fails to recognize, reconcile, or address: (1) the data collected to date indicating no detection of TCE in the indoor air of living spaces of homes overlying the highest levels of groundwater contamination; or (2) the statements of EPA Region 9 Assistant Director Site Cleanup Branch, Superfund Division, Kathleen Salyer, that sampling in buildings overlying lower levels of groundwater contamination is not warranted when sampling in homes overlying the areas of highest groundwater contamination show no vapor intrusion is occurring (See Exhibit H). Such action by the Regional Board is contrary to law, beyond the Regional Board's authority, an abuse of discretion and without support in the administrative record.

J. The Regional Board acted arbitrarily in issuing the Order in that the Regional Board has applied EPA Region 9's "guidelines" to only nine sites in the South Bay Area. Such action by the Regional Board is contrary to law, beyond the Regional Board's authority, an abuse of discretion and without support in the administrative record.

V. Petitioners are Aggrieved

Petitioners are aggrieved for the reasons set forth above.

VI. Petitioners' Requested Action by the State Board

Petitioners respectfully request that the State Board determine that the Regional Board's actions in requiring the Addendum and issuing the Order was inappropriate and improper, and that the State Board assume the power of the Regional Board to rescind or amend the Order in accordance with this Petition for Review and applicable law. Petitioners request the State Board to hold in abeyance this Petition for Review and Request for Hearing pending the Regional Board's consideration of Petitioners' request for reconsideration and further discussions between Petitioners and the Regional Board.

VII. Statement of Points and Authorities

Petitioners will provide a detailed statement of points and authorities in the event it activates this Petition for Review.

VIII. Statement of Transmittal of Petition to the Regional Board

A copy of this Petition has been transmitted to the Executive Officer of the Regional Board on February 24, 2014.

IX. Statement that the Issues Raised in the Petition Were Raised Before the Regional Board

Petitioners have raised the substantive issues and objections raised in this Petition with the Regional Board in meetings, letters, telephone calls, emails and other communications. Furthermore, by letter dated February 21, 2014, Petitioners submitted a request for reconsideration to the Executive Director of the Regional Board requesting that the Regional Board meet with Petitioners to discuss the project and to develop a path forward that addresses the concerns raised by Petitioners.

Petitioners reserve their right to request a hearing for the purpose of presenting additional evidence not previously presented to the Regional Board, in accordance with 23 CCR § 2050.6(b).

Respectfully submitted,

Date: February 24, 2014

By:
Christopher M. Roe
Cristina Armstrong
Fox Rothschild LLP
Attorneys for Petitioner Hewlett-Packard Company

Date: February 24, 2014

By: ______
Gordon C. Atkinson
Kathleen H. Goodhart
Cooley LLP
Attorneys for Petitioner Varian Medical Systems, Inc.

EXHIBIT A

January 23, 2014
File Nos. 43S0051 & 43S0188 (RWP)

Hewlett Packard Company
ATTN: Mr. Paul Paschke
1501 Page Mill Road
Palo Alto, CA 94304

paul_paschke@hp.com

Varian Medical Systems
ATTN: Mr. John Buchanan
3100 Hansen Way
Palo Alto, CA 94304

john.buchanan@varian.com

SUBJECT: Approval of *Addendum to the February 17, 2013 Revised Work Plan for Indoor Air Testing* and Requirement for Report for 640 Page Mill Road, Palo Alto, Santa Clara County

Dear Mr. Paschke and Mr. Buchanan:

This letter responds to your December 13, 2013, *Addendum to the February 17, 2013 Revised Work Plan for Indoor Air Testing* (Addendum). As explained below, I approve the Addendum and require you to submit a report documenting implementation of the Addendum.

Background

Our March 12, 2012, letter (Letter) conditionally approved Hewlett Packard's and Varian's February 17, 2013, *Revised Work Plan for Indoor Air Testing* (Workplan). You then implemented the Workplan in the off-property residential area of the California-Olive-Emerson (COE) plume and found no detectable levels of trichloroethene (TCE) levels in indoor air. However, an emerging body of data referenced in USEPA's December 3, 2013, *EPA Region 9 Guidelines for Vapor Intrusion Evaluations at South Bay National Priority List (NPL) Sites* (Guidelines) indicates that the COE vapor intrusion evaluation is incomplete without additional data. After USEPA discussed the basis for the Guidelines with you in several meetings, you submitted the Addendum and we emailed the Guidelines to you on December 5, 2013.

Addendum Summary

The Addendum incorporates the Workplan by reference and proposes the following additional activities to evaluate vapor intrusion:

- Sampling as follows:
  - On- and off-property commercial indoor air overlying plume areas with groundwater-TCE levels higher than 100 micrograms per liter, with the heating, ventilation, and air conditioning (HVAC) system turned off for at least 36 hours prior to and during sampling.
  - Off-Property residential indoor air overlying plume areas with groundwater-TCE levels higher than 50 micrograms per liter a concurrent with crawl space or basement air sampling at those residences previously sampled in April, July and September 2012, in cold weather.
- Collecting grab samples to evaluate potential preferential pathways for soil vapor to enter buildings.
- Using Method TO-15 Summa canisters over a 24-hour sampling period for residential buildings and over a 10-hour period for commercial buildings.
- Comparing the indoor air testing results with outdoor air levels, USEPA interim TCE indoor short-term response action levels, and long-term screening levels.
- Evaluating further phased potential indoor air vapor intrusion investigations, including potential sampling where commercial and residential buildings overly plume areas with groundwater-TCE levels higher than 5 micrograms per liter.

Regional Water Board Response

I hereby approve the Addendum as the next phase of vapor intrusion evaluation.

However, we recommend an alternate means of assessing average concentrations over a longer period of exposure than 24 hours while still utilizing the TO-15 canisters. Specifically, you can conduct two closely spaced sampling events one or two weeks apart, ideally timed during a period of colder weather. Regardless of whether these sampling events can be timed to coincide with cooler temperatures, multiple sampling rounds facilitate an evaluation of data variability from other factors than just temperature such as time-dependent changes in soil gas entry rates, building exchange rates, and intra-building mixing.

You are required to submit a report by **May 15, 2014**, documenting the implementation of the Addendum. The report should evaluate the sampling results and make recommendations for the next phase of vapor intrusion investigation.

This requirement for a report is made pursuant to Water Code Section 13267, which allows the Regional Water Board to require technical or monitoring program reports from any person who has discharged, discharges, proposes to discharge, or is suspected of discharging waste that could affect water quality. The attachment provides additional information about Section 13267 requirements. Any extension in the above deadline must be confirmed in writing by Regional Water Board staff.

If you have any questions, please contact Roger Papler of my staff at (510) 622-2435 [e-mail rpapler@waterboards.ca.gov].

Sincerely,

Digitally signed by Stephen Hill
Date: 2014.01.23 12:17:51 -08'00'

Bruce H. Wolfe
Executive Officer

Attachment: 13267 Fact Sheet
cc w/Attachment: Mailing List

MAILILNG LIST

USEPA ATTN: Ms. Melanie Morash 75 Hawthone Street San Francisco, CA 94105	morash.melanie@epa.gov
Santa Clara Valley Water District ATTN: Mr. George Cook 5150 Almaden Expressway San Jose, CA 95118	gcook@valleywater.org
City of Palo Alto Fire Department ATTN: Mr. Gordon Simpkinson 250 Hamilton Avenue Palo Alto, CA 94301	gordon.simpkinson@cityofpaloalto.org
Stantec Consulting, Inc. ATTN: Mr. Chris Maxwell 57 Lafayette Circle, 2nd Floor Lafayette, CA 94549	chris.maxwell@stantec.com
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Stanford Management Company ATTN: Ms. Annette Walton 2777 Sand Hill Road Menlo Park, CA 94303	nettie@stanford.edu

CALIFORNIA
Water Boards

EDMUND G. BROWN JR.
GOVERNOR

MATTHEW RODRIQUEZ
SECRETARY FOR
ENVIRONMENTAL PROTECTION

San Francisco Bay Regional Water Quality Control Board

Fact Sheet – Requirements for Submitting Technical Reports Under Section 13267 of the California Water Code

What does it mean when the Regional Water Board requires a technical report?
Section 13267[1] of the California Water Code provides that "...the regional board may require that any person who has discharged, discharges, or who is suspected of having discharged or discharging, or who proposes to discharge waste...that could affect the quality of waters...shall furnish, under penalty of perjury, technical or monitoring program reports which the regional board requires."

This requirement for a technical report seems to mean that I am guilty of something, or at least responsible for cleaning something up. What if that is not so?
The requirement for a technical report is a tool the Regional Water Board uses to investigate water quality issues or problems. The information provided can be used by the Regional Water Board to clarify whether a given party has responsibility.

Are there limits to what the Regional Water Board can ask for?
Yes. The information required must relate to an actual or suspected or proposed discharge of waste (including discharges of waste where the initial discharge occurred many years ago), and the burden of compliance must bear a reasonable relationship to the need for the report and the benefits obtained. The Regional Water Board is required to explain the reasons for its request.

What if I can provide the information, but not by the date specified?
A time extension may be given for good cause. Your request should be promptly submitted in writing, giving reasons.

Are there penalties if I don't comply?
Depending on the situation, the Regional Water Board can impose a fine of up to $5,000 per day, and a court can impose fines of up to $25,000 per day as well as criminal penalties. A person who submits false information or fails to comply with a requirement to submit a technical report may be found guilty of a misdemeanor. For some reports, submission of false information may be a felony.

Do I have to use a consultant or attorney to comply?
There is no legal requirement for this, but as a practical matter, in most cases the specialized nature of the information required makes use of a consultant and/or attorney advisable.

What if I disagree with the 13267 requirements and the Regional Water Board staff will not change the requirement and/or date to comply?
You may ask that the Regional Water Board reconsider the requirement, and/or submit a petition to the State Water Resources Control Board. See California Water Code sections 13320 and 13321 for details. A request for reconsideration to the Regional Water Board does not affect the 30-day deadline within which to file a petition to the State Water Resources Control Board.

If I have more questions, whom do I ask?
Requirements for technical reports include the name, telephone number, and email address of the Regional Water Board staff contact.

Revised January 2014

[1] All code sections referenced herein can be found by going to www.leginfo.ca.gov.

EXHIBIT B

California Regional Water Quality Control Board
San Francisco Bay Region

Matthew Rodriquez
Secretary for Environmental Protection

1515 Clay Street, Suite 1400, Oakland, California 94612
(510) 622-2300 • Fax (510) 622-2460
http://www. waterboards.ca.gov/sanfranciscobay

Edmund G. Brown, Jr.
Governor

Date: March 12, 2012
File Nos. 43S0051 & 43S0188 (RWP)

Hewlett Packard Company
ATTN: Mr. Paul Paschke
1501 Page Mill Road
Palo Alto, CA 94304

paul_paschke@hp.com

Varian Medical Systems
ATTN: Mr. Alan Palter
3100 Hansen Way
Palo Alto, CA 94304

alan.palter@varian.com

SUBJECT: Approval of *Revised Work Plan for Indoor Air Testing - COE Study Area* for 640 Page Mill Road and 601 California Avenue, Palo Alto, Santa Clara County

Dear Mr. Paschke and Mr. Palter:

This letter responds to your February 17, 2012, *Revised Work Plan for Indoor Air Testing - COE Study Area* (Workplan) for the subject site. As explained below, I approve the Workplan. You are required to submit a report documenting the implementation of the Workplan **60 days after collecting the indoor air data**.

The Regional Water Board regulates the site under Order No. 94-130 (Order). Our June 1, 2011, letter (Letter) required you to submit a workplan to evaluate potential indoor air vapor intrusion in the off-property area.

Workplan Summary

The Workplan proposes the following activities:

- Testing indoor air quality in the following areas:
  - Residential properties where trichloroethene (TCE) is greater than 50 micrograms per liter (ug/l) in groundwater.
  - Commercial properties where TCE is greater than 100 ug/l in groundwater.
- Pre-sampling building walk through to identify indoor air sampling locations.
- Collecting indoor and outdoor air samples with Summa canisters from residential buildings over a 24-hour period and from commercial buildings over an 8-hour period.
- Analyzing the indoor air samples using EPA Method TO 15.

Regional Water Board Response

USEPA has also reviewed and approved the Workplan.

The Workplan does not completely satisfy the requirements of the Letter for the following reasons:

- The Workplan did not specify a sufficiently sensitive hand-held screening device. A screening device with sensitivity in the parts per billion range is not sufficiently sensitive to screen for potential indoor air vapor intrusion.
- The Workplan did not specify testing the indoor air of commercial buildings with the heating, ventilation and air conditioning (HVAC) system off. Air testing the commercial buildings with HVAC system on does not account for HVAC use and settings that change over time and with different building owners.

I hereby approve the Workplan subject to the following conditions:

- Using a sufficiently sensitive hand-held screening device. One option is to use a photoionization detector with sensitivity in the low parts per billion range.
- Testing the indoor air of commercial buildings with the HVAC system off and, if any of the results exceed indoor air ESLs, repeating the testing with the HVAC system on.

You are required to submit a report documenting the implementation of the Workplan by **60 days after collecting the indoor air data**. The report shall include an evaluation of the definition of vapor intrusion and a proposal for additional investigation to fully define the extent of vapor intrusion concerns.

This requirement for a report is made pursuant to Water Code Section 13267, which allows the Regional Water Board to require technical or monitoring program reports from any person who has discharged, discharges, proposes to discharge, or is suspected of discharging waste that could affect water quality. The attachment provides additional information about Section 13267 requirements. Any extension in the above deadline must be confirmed in writing by Regional Water Board staff.

You are required to submit all documents in electronic format to the State Water Resources Control Board's GeoTracker database and in hard copy format to this office. Guidance for electronic information submittal is available at http://www.waterboards.ca.gov/water_issues/programs/ust/electronic_submittal.

If you have any questions, please contact Roger Papler of my staff at (510) 622-2435 [e-mail rpapler@waterboards.ca.gov].

Sincerely,

Digitally signed by Stephen Hill
Date: 2012.03.12 13:02:37
-07'00'

Bruce H. Wolfe
Executive Officer

Attachment
cc w/attach:

USEPA
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USEPA
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Santa Clara Valley Water District
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gcook@valleywater.org

City of Palo Alto Fire Department
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California Regional Water Quality Control Board
San Francisco Bay Region

Mathew Rodriquez
Secretary for Environmental Protection

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Edmuod G. Brown, Jr.
Governor

Fact Sheet – Requirements For Submitting Technical Reports Under Section 13267 of the California Water Code

What does it mean when the Regional Water Board requires a technical report?
Section 13267[1] of the California Water Code provides that "…the regional board may require that any person who has discharged, discharges, or who is suspected of having discharged or discharging, or who proposes to discharge waste…that could affect the quality of waters…shall furnish, under penalty of perjury, technical or monitoring program reports which the regional board requires."

This requirement for a technical report seems to mean that I am guilty of something, or at least responsible for cleaning something up. What if that is not so?
The requirement for a technical report is a tool the Regional Water Board uses to investigate water quality issues or problems. The information provided can be used by the Regional Water Board to clarify whether a given party has responsibility.

Are there limits to what the Regional Water Board can ask for?
Yes. The information required must relate to an actual or suspected or proposed discharge of waste (including discharges of waste where the initial discharge occurred many years ago), and the burden of compliance must bear a reasonable relationship to the need for the report and the benefits obtained. The Regional Water Board is required to explain the reasons for its request.

What if I can provide the information, but not by the date specified?
A time extension may be given for good cause. Your request should be promptly submitted in writing, giving reasons.

Are there penalties if I don't comply?
Depending on the situation, the Regional Water Board can impose a fine of up to $5,000 per day, and a court can impose fines of up to $25,000 per day as well as criminal penalties. A person who submits false information or fails to comply with a requirement to submit a technical report may be found guilty of a misdemeanor. For some reports, submission of false information may be a felony.

Do I have to use a consultant or attorney to comply?
There is no legal requirement for this, but as a practical matter, in most cases the specialized nature of the information required makes use of a consultant and/or attorney advisable.

What if I disagree with the 13267 requirements and the Regional Water Board staff will not change the requirement and/or date to comply?
You may ask that the Regional Water Board reconsider the requirement, and/or submit a petition to the State Water Resources Control Board. See California Water Code sections 13320 and 13321 for details. A request for reconsideration to the Regional Water Board does not affect the 30-day deadline within which to file a petition to the State Water Resources Control Board.

If I have more questions, whom do I ask?
Requirements for technical reports include the name, telephone number, and email address of the Regional Water Board staff contact.

Revised January 2011

[1] All code sections referenced herein can be found by going to www.leginfo.ca.gov.

EXHIBIT C

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

December 13, 2012

REDACTED

This letter is to confirm in writing the results of EPA's indoor air sampling conducted at your home in April 2012. The information provided here reiterates the results we discussed by phone following our sampling event. This sampling was performed in connection with the former Hewlett-Packard facilities at 620-640 Page Mill Road and the former Varian Associates, Inc. facility at 601 California Avenue, Palo Alto, CA. It is important to note that the contaminated groundwater in the area is not used for drinking water or any household use.

Trichloroethylene (TCE) was not detected in your home. Please see the attached chart for the results. The indoor air sampling results from the 12 residences sampled in the area, including your home, indicate that vapor intrusion from subsurface groundwater contamination does not appear to be occurring. Therefore, no additional air sampling is recommended at your home.

Thank you again for your cooperation and participation in this air sampling investigation. Please do not hesitate to contact us if you have any questions regarding the sample results or the air investigation. You may contact us at (415) 972-3982 or salazar.matt@epa.gov or Vicki Rosen, EPA Community Involvement Coordinator at (415) 972-3244 or rosen.vicki@epa.gov.

Sincerely,

Matt Salazar, P.E.
EPA Project Manager

EXHIBIT D

Hewlett-Packard Company
3404 East Harmony Road
Mail Stop 13
Fort Collins, CO 80528
USA

hp.com

October 23, 2013

Via Overnight Delivery

Alexis Strauss, Deputy Regional Administrator
USEPA REGION 9
75 Hawthorne Street
Mail Code: ORA-1
San Francisco, CA 94105
Email: strauss.alexis@epa.gov

Stephen Hill, Toxics Cleanup Division Chief
San Francisco Bay Regional Water Quality Control Board
1515 Clay St. Suite 1400
Oakland, CA 94612
Email: shill@waterboards.ca.gov

Paul E. Paschke
Environmental Program Manager
Tel +1 970 898 0573
Fax +1 970 778 4192
Paul.Paschke@hp.com

RE: Renewed Request for Meeting and for Extension of Time for Comments Regarding Ongoing Study at Hewlett-Packard (620-640 Page Mill Road) (EPA ID: CAD980884209) Site, 395 Page Mill Road, 601 California Avenue and California-Olive-Emerson (COE) Study Area

Deputy Administrator Strauss and Mr. Hill:

On September 12, 2013, United States Environmental Agency Region 9 surprised Hewlett-Packard Company ("HP") and Varian Medical Systems, Inc. ("Varian") by announcing to them its intention to impose a new approach and a new set of standards and requirements for a vapor intrusion investigation that has been going on for more than two years in the COE area of Palo Alto. USEPA staff explained that the new requirements would be issued through a letter from the San Francisco Bay Regional Water Quality Board ("the Letter").

On September 18, 2013, HP and Varian requested a meeting with Deputy Administrator Strauss and the Regional site project team. Among other things, we sought to discuss and understand – before the Letter was finalized – USEPA's decision to reverse conclusions that USEPA had made and communicated to residents in the Palo Alto study area in December 2012. In addition, we wanted to stress our desire for thoughtfulness and certainty as the project moves forward and discuss why changes are necessary when indoor air testing in all 20 buildings tested in Palo Alto so far has failed to detect any vapor intrusion to living or working space. The meeting did not occur due to the government shutdown.

Nevertheless, the day USEPA returned from the shutdown it directed the Water Board to issue the Letter, in draft, to HP and Varian. The communication from the Water Board requires that any comment that the companies may have on the draft Letter and new standards and requirements must be received by the Water Board by October 25, 2013, 5 business days from the day the Letter was received. The Letter requires that the companies generate a revised work plan to meet the new standards and requirements by November 30, 2013.

It appears to us that USEPA Region 9 is using the Letter and its attachment to set down in writing for the first time significant new vapor intrusion guidance that the Region has not issued or adopted through any formal process. The Region's new guidance would be issued by the Water Board under Section 13267 of the California Water Code and not by USEPA, and therefore would be appealable by the companies to the State Water Board even though the Water Board did not formulate the underlying standards and requirements contained in the letter. Adding to the confusion and uncertainty we are experiencing, is how this interrelates with the USEPA headquarters (Washington DC) review of public comment on its draft "Final" vapor intrusion guidance. We are concerned that guidance may turn out to differ in significant respects from what Region 9 has included in the Letter.

It does not seem fair or appropriate to ask residents and businesses to open their living and working spaces to additional indoor air testing when the USEPA's views on the appropriate protocol are in such a state of flux. Assurances provided to residents just months ago would need to be reversed, the new requirements and standards are not in adopted guidance (and thus may be changed again), and we know that US EPA headquarters may issue formal adopted guidance in the near future on this very set of protocols.

We still believe that a meeting is the best way to discuss our concerns and understand the change in the USEPA's approach for the COE study area. We would like to have that meeting before comments are provided on the Letter. Regional staff has indicated that Deputy Administrator Strauss is not available to meet with the companies directly and the first date that any USEPA representatives would meet with the companies is in the week of November 18. That would be shortly before the revised work plan is due, and weeks after we are required to provide comments on the Letter. Therefore, we are reiterating our request for a meeting and asking, in parallel, for an extension to the comment period for the draft Letter and the associated standards and requirements.

We respectfully request:

1. That Deputy Regional Administrator Strauss or other senior USEPA management consider meeting with the companies on this important matter. Based on the results of the indoor air sampling to date there is no reason for urgency at the COE site that might

justify rushing through a process that may result in inconsistent and confusing statements to the community. HP and Varian have a very long history of working well, cooperatively and responsibly with the Region and the Water Board, including on this sensitive project in a community that is extremely important to us. Palo Alto is our home, and it is where many of our employees both live and work. We have a strong desire to complete this investigation in a way that provides assurance to the community that the companies and the agencies are proceeding thoughtfully, respectful of community concerns and interests. Reversing so abruptly the current approach and the decisions recently communicated about this indoor air investigation, without any new guidelines or criteria that have been formally adopted by the Region, seems to us to set the community up for continuing uncertainty and unnecessary disruption.

2. A stay of the deadline for our written comments to the Letter and the attachment until we have a chance to meet, as requested in our September 18 letter. We believe an opportunity to meet with USEPA and the Water Board to meaningfully discuss our concerns about the process and to ask questions about the basis for USEPA Region 9's new standards and requirements will be most productive before we provide substantive written comments draft Letter.

3. That, in any event, the Water Board not issue the Letter in final form until we have the requested meeting.

We are anxious to move forward to complete the testing in this important project. All of the stakeholders in the process deserve the agencies' and the companies' best efforts to proceed thoughtfully and in a way that justifies the community's confidence.

Please let us know your agencies' soonest availability to meet to discuss this. Also, please let us know as soon as possible whether the Water Board and USEPA agree to extend the October 25 deadline for comments to the Letter until a reasonable period of time after the requested meeting. If that is not possible, please confirm that the Letter will not be issued in final form until we have the chance to meet and discuss.

Respectfully submitted,

HEWLETT-PACKARD Company	VARIAN MEDICAL SYSTEMS, INC.
Paul E. Paschke Environmental Program Manager	Alan Palter Director, Environmental Affairs

cc: Melanie Morash, Regional Project Manager
Kathleen Salyer, Assistant Director, Superfund Division, Region 9
Roger Papler, RWQCB

Thelma Estrada, Regional Counsel
Jennifer Morris, Global SER & EHS Counsel for HP
Christopher Roe, HP outside counsel
John Buchanan, Manager, Environmental Affairs, Varian Medical Systems, Inc.
Gordon Atkinson, Varian outside counsel

EXHIBIT E

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region 9
75 Hawthorne Street
San Francisco, CA 94105

MEMORANDUM

DATE: November 26, 2013

SUBJ: Hewlett Packard 620-640 Page Mill Road Superfund Site
Comments on November 2013 Indoor Air Testing Work Plan Addendum

FROM: Melanie Morash, Remedial Project Manager
US EPA Region 9

TO: Roger Papler, Engineering Geologist
San Francisco Bay Regional Water Quality Control Board

Thank you for the opportunity to review and comment on the above-referenced document. Please do not hesitate to contact me if there are any questions, or if I can be of further assistance (morash.melanie@epa.gov / 415-972-3050).

General Comment

EPA recognizes and appreciates all of the vapor intrusion work activities that have been conducted to date at the subject site, and hopes to work closely with HP and Varian (the Responsible Parties or RPs for the site) and the San Francisco Bay Regional Water Quality Control Board (Regional Water Board) to finalize this Work Plan Addendum in time to complete the next round of vapor intrusion-related sampling before the end of winter (January - February 2014), during which time the potential for vapor intrusion may be higher.

Recognizing the temporal and spatial variability of indoor air and subsurface concentrations, EPA generally recommends collecting more than one round of sampling and from multiple locations. In reviewing the lines of evidence that have been collected for the HP Site, EPA Region 9 has identified that multiple rounds of indoor air sampling have not been collected, and that sampling has not been conducted during colder weather months, when the potential for vapor intrusion may be higher. EPA appreciates HP and Varian's cooperation in preparing an Indoor Air Testing Work Plan Addendum that seeks to address these issues and assess vapor intrusion potential during the colder months of the year.

Comment #1: "Revisions to Short Term Action Levels" section, last paragraph

A guidance document is referenced as being included in Exhibit A to the Indoor Air Testing Addendum (Addendum), however this document was not included with the submittal. Please revise Addendum accordingly, or otherwise note in the text that this or other relevant guidance documents will be included when available. EPA Region 9 plans to shortly issue guidelines and supplemental information to the Regional Water Board for vapor intrusion investigations at the South Bay state-lead groundwater National Priorities List (NPL) sites, inclusive of the subject site. This information, once finalized, would be appropriate to cite here.

Comment #2: "Revisions to Short Term Action Levels" section

Please revise this section to include the following TCE short-term action levels:

Exposure Scenario	***Prompt Response Action Level (micrograms/cubic meter)***
Residential	2 $\mu g/m^3$
Commercial/Industrial (8-hour workday)	9 $\mu g/m^3$
(10-hour workday)	7 $\mu g/m^3$

Comment #3: "Commercial Building Testing with HVAC System Off" section

This section states, "Collection of indoor air samples with the HVAC system off is intended to provide EPA additional data with which to evaluate possible soil gas transport into buildings and the results would not be considered representative of building indoor air quality under normal operating conditions."

Please revise this section by adding the following sentence: "However, these HVAC-off sampling results will inform the vapor intrusion investigations in the development of the full range of possible exposure scenarios."

Comment #4: "Commercial Building Testing with HVAC System Off" section

Please revise this section to clarify that testing will occur at both *on*-property buildings located in the former source areas, as well as buildings in the *off*-property vapor intrusion study area. During a meeting between EPA Region 9, the Regional Water Board, and representatives of the property owner of the 601 California Avenue and 650 Page Mill Road buildings, it was indicated to the Agencies that the owners intend to cooperate with the RPs in coordinating sampling efforts.

Comment #5: "Commercial Building Testing with HVAC System Off" section

Please revise this section to specify that pathway sampling in commercial buildings shall also be conducted, as part of the "multiple-lines-of-evidence" vapor intrusion evaluation. Typical pathway samples may include from near floor drains and loose-fitting pipes in bathrooms and office kitchen areas, near electrical outlets, in stairwells, and from certain small, apparently poorly-ventilated rooms or spaces (for example, elevator mechanical rooms, elevator shafts, or server/utility closets).

Comment #6: "Commercial Building Testing with HVAC System Off" section

This section states, "Sample duration will be selected depending on normal building occupancy patterns (e.g., 8-hour, 10-hour or 12-hours)."

Based on input from commercial building owners and tenants, EPA Region 9 recommends use of the 10-hour workday for determining the appropriate action levels for commercial/industrial buildings. However, site-specific adjustments can be made as needed for workplaces with longer work schedules. Please revise this section accordingly.

Comment #7: "Grab Sample Collection" section

The last sentence of this section states, "Grab sample results are not considered representative of indoor air quality and therefore are not appropriate for comparison to indoor air screening or action levels established for this project."

Please revise this section to add that grab samples, however, may be used to inform the vapor intrusion investigation, for example, by identifying additional sampling locations for comparison to the project screening levels or by helping to develop the conceptual site model for the subject site.

Comment #8: "Cold Season Resampling of Residential Buildings" section

In reviewing the lines of evidence that have been collected for the HP Site, EPA Region 9 has identified as a data gap the lack of crawlspace sampling, which must be addressed in order to complete the vapor intrusion evaluations.

Please revise this section to include concurrent crawlspace/basement (as appropriate) sampling with residential indoor air breathing zone sampling in the Off-Property Study Area, together with a proposed methodology for sample placement.

Comment #9: "Cold Season Resampling of Residential Buildings" section, 2nd paragraph

This section states, "For comparability, samples will be collected...over 24 hours, consistent with the prior sampling."

EPA Region 9 supports the use of longer-term passive samplers to help assess the temporal variability of indoor air vapor intrusion-related contaminant concentrations. The longer-term sampler provides a greater duration over which to average indoor air vapor intrusion levels for the purposes of completing the vapor intrusion evaluation, however EPA Region 9 is open to discussing sampling strategies for both the passive sampler and TO-15 canister.

Comment #10: "Cold Season Resampling of Residential Buildings" section, last paragraph

This section states, "EPA will provide notification and secure access from property owners/tenants and provide public outreach information to property owners or tenants regarding the justification for re-sampling their homes."

Consistent with the approach for the first round of indoor air sampling, EPA will continue to provide community involvement and outreach support for the subject site, and will provide notification and public outreach information to affected community members. However, EPA does not plan to change its approach regarding securing access, and encourages the RPs to first make their best efforts to secure access from residents and commercial/industrial business owners and tenants for the purposes of completing the vapor intrusion evaluations. EPA will assist with obtaining access in the event that the RPs are unsuccessful in their efforts with property owners/tenants.

Comment #11: "Cold Season Resampling of Residential Buildings" section, 1st paragraph

This section proposed the following sampling approach: "...previously sampled residential buildings located on Pepper Avenue and one multi-family residential building located on Sheridan Avenue would comprise the subset of buildings to be resampled."

EPA's preferred approach consists of increasing the subset of residential buildings which will be targeted for sampling in January and February 2014 to all those residential buildings identified in the original study area – overlying the original 50 microgram per liter (μg/L) shallow-zone TCE groundwater contour line, as identified in the original Work Plan for the subject site, and based on groundwater data collected in June and September 2011. An alternate, though less favored, approach consists of sampling at the twenty-one residential (single and multi-family) buildings that were previously sampled during the spring/summer 2012 sampling events.

Regardless of which single-family residences are sampled, EPA recommends that the next round of testing include, at a minimum, all of the multi-family residential buildings where volatile organic compounds (VOCs) were previously detected in pathway (elevator shafts, sumps, drains) or garage samples, which includes buildings 19, 20 and 21.

A discussion of the confidence level and uncertainty in the groundwater data and contour lines would also be appropriate here, and what additional buildings (residential or commercial) might be identified for sampling based on any alternate curve fittings or regression analysis.

Comment #12: "Cold Season Resampling of Residential Buildings" section

Please revise this section to propose a more detailed step-out process for expanding the sampling program. For example, discussion of timing of step-out to remaining homes overlying the 50 μg/L TCE groundwater contour that have not yet been sampled or otherwise re-sampled during the colder weather.

Comment #13: "Supplemental Vapor Intrusion Assessment" section

This section should also be expanded to identify and highlight the residential and commercial buildings located above the 5 µg/L shallow-zone TCE groundwater contour line, using the most recently collected groundwater data for the subject site, together with an accompanying uncertainty analysis, as referred to above.

Comment #14: "Supplemental Vapor Intrusion Assessment" section

This section states that the supplemental assessment will include, "Visual observations of buildings to ascertain, to the extent practical from external observation, whether a given building likely has a basement or other potential preferential pathway of concern."

It is the Agency's experience that for certain buildings, external visual assessment is insufficient to properly evaluate a building's potential for vapor intrusion, and that comprehensive building walk-throughs are necessary to assess preferential pathways or other building features that may elevate vapor intrusion potential. However, external visual assessment can be a useful tool for adding buildings to a study area. Please revise this section accordingly to reflect that building walkthroughs will be necessary at each building in the Off-Property Study Area.

Comment #15: "Supplemental Vapor Intrusion Assessment" section

This section states, "Information from these activities will be considered, together to assess what, if any, additional actions may be warranted."

EPA supports the initial agreed upon prioritization of conducting vapor intrusion evaluations at commercial and residential buildings overlying higher TCE shallow A-zone groundwater contamination (greater than 50 µg/L for residential buildings and greater than 100 µg/L for commercial buildings). However, the Agency would like to clarify that the Work Plan Addendum should be revised to define the Vapor Intrusion Off-Property Study Area as the area bounded by the estimated TCE shallow zone groundwater contamination area greater than 5 µg/L.

While a phased approach to the remaining sampling is acceptable, full evaluation drawing on the multiple-lines-of-evidence approach, out to the off-property groundwater boundary line, or 5 µg/L for TCE in shallow zone groundwater, will be expected, and a discussion of the timing and strategy for conducting step-out sampling, as appropriate, to 5 µg/L for TCE should be discussed here. A comprehensive evaluation of the multiple lines of evidence collected for each property should be used in determining the potential for vapor intrusion at particular buildings and whether additional investigation and/or mitigation is warranted. Any proposal to exclude particular buildings from indoor air sampling must be supported by a robust, site- and building-specific multiple-lines-of-evidence analysis.

As previously reported in documents prepared by Stantec Consulting, groundwater at the subject site is generally shallow, ranging between approximately 5 feet below ground surface (bgs) to 55 feet bgs, with the A1U-zone TCE plume overlying groundwater at about 20 feet bgs. Ongoing data collection efforts at other similar vapor intrusion sites in Region 9, as well as nationally, have shown vapor intrusion potential into buildings overlying lower groundwater TCE concentrations (less than 50 µg/L for residential buildings and less than 100 µg/L for commercial buildings), at levels exceeding health protective indoor air levels. Factors include, but are not limited to, location relative to source areas, impacts due to seasonal fluctuations in groundwater levels, preferential pathways into a building and other building-specific characteristics that facilitate upward migration of subsurface vapors into interior living and work spaces.

The use of the TCE 5 µg/L groundwater concentration as defining the extent of the Vapor Intrusion Evaluation Study Area is reasonable, supported by use of EPA's vapor intrusion screening level calculator, the generic default groundwater-to-indoor air attenuation factor of 0.001 and the appropriate Henry's Law conversion, empirical data, and mathematical modeling.

EPA supports a phased multiple-lines-of-evidence approach in prioritizing vapor intrusion investigations, for example: (1) colder weather indoor air sampling event and commercial building HVAC-off and HVAC-on sampling within the original Off-Property Study Area; (2) data evaluation and identification of data gaps, with subsequent additional multiple-lines-of-evidence data collection and analysis; (3) targeted step-out's to specific commercial/residential buildings or streets overlying lower contaminant concentration contour lines; and finally (4) full step-out and building-specific evaluation to off-property vapor intrusion study boundary line, or 5 µg/L TCE.

EXHIBIT F

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Region 9
75 Hawthorne Street
San Francisco, CA 94105

December 3, 2013

Stephen Hill, Chief
Toxics Cleanup Division
California Regional Water Quality Control Board – SF Bay Region
1515 Clay Street #1400
Oakland, CA 94612

SUBJECT: EPA Region 9 Guidelines and Supplemental Information Needed for Vapor Intrusion Evaluations at the South Bay National Priorities List (NPL) Sites

Dear Mr. Hill:

The United States Environmental Protection Agency (EPA) Region 9 appreciates the opportunity to work with the San Francisco Bay Regional Water Quality Control Board (Regional Water Board) in conducting vapor intrusion evaluations at the following Regional Water Board-lead National Priorities List (NPL) or Superfund sites in the South San Francisco Bay Area (South Bay Sites) where trichloroethene (TCE) or tetrachloroethene (PCE) are contaminants of potential concern:

- AMD 901/902/TRW Microwave/Phillips and Offsite Operable Unit Combined Sites in Sunnyvale
- AMD 915 DeGuigne Drive Site in Sunnyvale
- Monolithic Memories Site (also known as AMD 1165/1175 Arques Avenue Site) in Sunnyvale
- Fairchild Semiconductor Site in South San Jose
- Hewlett Packard 620-640 Page Mill Road Site in Palo Alto
- Intersil/Siemens Site in Cupertino and Sunnyvale
- National Semiconductor Site (also known as Texas Instruments Site) in Sunnyvale
- Synertek Building 1 Site in Santa Clara
- Teledyne/Spectra-Physics Sites in Mountain View

EPA recognizes and appreciates all of the vapor intrusion work activities conducted to date at these sites. Pursuant to recent discussions with EPA Region 9, the Regional Water Board, and the potentially responsible party (PRP) representatives on planned upcoming vapor intrusion work activities, EPA

Region 9 is providing this letter to outline EPA's recommended TCE interim short-term indoor air response action levels and guidelines and clarify the use of California-modified indoor air screening levels that should be applied when assessing and responding to TCE and PCE subsurface vapor intrusion into indoor air.

In addition, this letter includes, as outlined in the Attachment, additional information and specific requirements for vapor intrusion evaluations for the South Bay Sites, consistent with the "multiple-lines-of-evidence" approach in EPA's 2013 Office of Solid Waste and Emergency Response (OSWER) *External Review Draft – Final Guidance for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Sources to Indoor Air*. In reviewing the multiple lines of evidence that have been collected for the South Bay Sites, EPA Region 9 has identified data gaps that must be filled to fully evaluate the potential for vapor intrusion into buildings overlying the South Bay Sites' contamination.

EPA Region 9 recommends that the following guidelines and supplemental information be incorporated, as appropriate, into existing and future Vapor Intrusion Evaluation Work Plans (Work Plans) for each of the South Bay Sites:

- Interim TCE Indoor Air Short-term Response Action Levels and Guidelines
- PCE Indoor Air Screening Levels
- Residential Building Sampling Approach – Multiple Rounds of Sampling including Colder Weather and Crawlspace Sampling
- Commercial Building Sampling Approach – Building Ventilation System (HVAC)-Off, HVAC-On and Pathway Sampling
- On-Property Study Area Building Sampling
- Phased Approach and Clarification of Vapor Intrusion Off-Property Study Areas to Include Buildings Overlying 5 µg/L TCE Shallow-Zone Groundwater Contamination

EPA Region 9 will continue to provide technical vapor intrusion and community involvement and outreach support for the South Bay Sites.

If you have any technical questions, please contact Melanie Morash of my staff at (415) 972-3050 or by e-mail to morash.melanie@epa.gov.

Sincerely,

Kathleen Salyer
Assistant Director, Superfund Division
California Site Cleanup Branch

Attachment: EPA Region 9 Guidelines and Supplemental Information for VI Evaluations

Attachment: EPA Region 9 Guidelines and Supplemental Information Needed for Vapor Intrusion Evaluations at the South Bay National Priorities List (NPL) Sites

EPA Region 9 recommends that the following guidelines and supplemental information be incorporated, as appropriate, into existing and future Vapor Intrusion Evaluation Work Plans (Work Plans) for each of the South Bay NPL Sites, primarily with subsurface trichloroethene (TCE) and tetrachlorethene (PCE) contamination.

The additional information and specific requirements requested are consistent with the "multiple-lines-of-evidence" approach in EPA's 2013 Office of Solid Waste and Emergency Response (OSWER) *External Review Draft – Final Guidance for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Sources to Indoor Air.*

In reviewing the multiple lines of evidence that have been collected for the South Bay Sites, EPA Region 9 has identified data gaps that must be filled in order to fully evaluate the potential for vapor intrusion into buildings overlying the subsurface contamination at each individual South Bay Site.

Item #1 – Interim TCE Indoor Air Short-term Response Action Levels and Guidelines

In September 2011, EPA published its *Toxicological Review of Trichloroethylene in Support of the Integrated Risk Information System (IRIS).* Recent findings on TCE conclude that women in the first trimester of pregnancy are one of the most sensitive populations to TCE short-term inhalation exposure due to the potential for heart malformation for the developing fetus.

EPA uses a level of concern for non-cancer effects as a ratio of the exposure concentration to a safe dose including an additional margin of safety, called a reference concentration (RfC). This ratio is defined as a Hazard Quotient and abbreviated "HQ". The IRIS assessment derived an inhalation RfC for continuous inhalation exposure to TCE, which is 2 micrograms per cubic meter (2 $\mu g/m^3$).

Because this is a developmental effect, the critical period for exposure is considered to be within an approximate 3-week period in the first trimester of pregnancy during which the heart develops. Scientific information on the exact critical period of exposure for this health impact is not currently available; however, general risk assessment guidelines for developmental effects indicate that exposures over a period as limited as 24 hours[1] may be of concern for some developmental toxicants.

In light of this RfC information, EPA Region 9 is using health protective response action levels and guidelines to address short-term inhalation exposures to TCE in indoor air from the subsurface vapor intrusion pathway. The purpose of these interim response action levels and guidelines is to be protective of one of the most sensitive and vulnerable populations, women in their first trimester of pregnancy, because of the potential for cardiac malformations to the developing fetus during this short timeframe.

These guidelines identify women of reproductive age as the sensitive population of concern, rather than only pregnant women, because some women may not be aware of their pregnancy during the first trimester.

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[1] U.S. EPA. Guidelines for Developmental Toxicity Risk Assessment. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC, EPA/600/FR-91/001, 1991

Assessment of TCE Inhalation Vapor Intrusion Exposure and Prompt Response Actions in Residential and Commercial/Industrial Buildings: The interim TCE indoor air short-term response action levels should be included in Vapor Intrusion Evaluation Work Plans (Work Plans) for assessing and responding to inhalation exposures to TCE in residential and commercial buildings caused by subsurface vapor intrusion at the South Bay Sites.

Interim TCE Indoor Air Short-Term Response Action Levels Residential and Commercial TCE Inhalation Exposure from Subsurface Vapor Intrusion South Bay NPL Sites	
Exposure Scenario	***Prompt Response Action Level (HQ=1)***[2]
Residential *	2 $\mu g/m^3$
Commercial/Industrial 8-hour workday	9 $\mu g/m^3$
10-hour workday (South Bay Sites) **	7 $\mu g/m^3$

* The Residential HQ=1 prompt response action level is equivalent to the inhalation reference concentration (RfC) since exposure is assumed to occur continuously over a 24-hour period.

** Commercial/Industrial prompt response action levels are calculated as the time-weighted average from the RfC - 9 $\mu g/m^3$ for an 8-hour workday; 7 $\mu g/m^3$ for a 10-hour workday. Based on input from commercial building owners and tenants, EPA Region 9 recommends use of the 10-hour workday for determining the appropriate response action levels for commercial/industrial buildings at the South Bay Sites. Time-weighted adjustments can be made as needed for workplaces with longer work schedules.

Note: These prompt response action levels are near the lower end of the Superfund Health Protective Cancer Risk Range;[3] thus, the Superfund Health Protective Risk Range for both long-term and short-term exposures is: 0.4 – 2 $\mu g/m^3$ for residential exposures and 3 – 9 $\mu g/m^3$ for 8-hour/day commercial/ industrial exposures.[4]

TCE Indoor Air Concentration > Prompt Response Action Level (HQ=1): In the event the indoor air TCE concentration related to subsurface vapor intrusion is detected above the prompt response action levels (HQ=1), then interim mitigation measures should be evaluated and implemented quickly, and their effectiveness (defined as a reduction of the TCE indoor air concentration to below HQ=1 level) confirmed promptly (e.g., all actions completed and confirmed within a few weeks).

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[2] There is a need to identify TCE exposures that exceed the HQ=1 level by a magnitude sufficient enough that a more urgent response is prudent; it is EPA Region 9 practice to take immediate action to address exposures at or above an HQ=3 level.

[3] For cancer causing chemicals, the Superfund Health Protective Risk Range encompasses the range of concentrations EPA considers to be protective, from 1 to 100 in a million increased lifetime cancer risk. The level that falls into the most protective end of the risk range – 1 in a million increased lifetime risk – is what is used as the screening level for any particular chemical. After identifying the health protective levels, EPA then compares measured values to the lowest, most health-protective, end of the range. Although levels of exposure anywhere within the range may be acceptable, EPA's goal for indoor air exposures to Superfund site-related chemicals is to keep exposures as low as reasonably possible within the Superfund Health Protective Risk Range.

[4] U.S. EPA Region 9 May 2013 Regional Screening Levels: http://www.epa.gov/region9/superfund/prg/ Accessed November 2013.

Implementation of Interim Measures to Mitigate TCE Short-term Exposure: The following interim response actions (mitigation measures) should be considered along with how quickly they can be implemented to reduce exposure to below the TCE short-term response action levels:

- Increasing building pressurization and/or ventilation mechanically with fans or the building ventilation system by increasing outdoor air intake
- Installing and operating engineered, sub-floor exposure controls (sub-slab and/or crawlspace depressurization; or in some cases a soil vapor extraction system)
- Eliminating exposure by temporary relocation, which may be indicated when immediate response actions are warranted.

The following interim measures may also be considered, but may have limited effectiveness and require additional monitoring to verify their effectiveness:

- Sealing and/or ventilating potential conduits where vapors may be entering building
- Treating indoor air (carbon filtration, air purifiers)

Item #2 – PCE Indoor Air Screening Levels

EPA acknowledges that the California-modified indoor air screening levels for PCE differ from EPA's May 2013 Regional Screening Levels (RSLs) for PCE. EPA Region 9 would like to clarify that the California EPA Office of Health Hazard Assessment's PCE toxicity value should be used for all NPL sites within California, which includes the South Bay Sites.

Work Plans and reports should be prepared or revised, as appropriate, to evaluate indoor air sampling results using the California-modified indoor air screening level of 0.4 $\mu g/m^3$ for residential exposures and 2 $\mu g/m^3$ for commercial/industrial exposures. The Superfund Health Protective Risk Range for PCE is bounded by the 10^{-6} excess cancer risk (low end) and by the non-cancer HQ=1 (high end). Specifically, the Superfund Health Protective Risk Range for PCE is 0.4 – 40 $\mu g/m^3$ for residential exposures and 2-180 $\mu g/m^3$ for commercial/ industrial exposures.

Item #3 – Residential Building Sampling Approach – Multiple Rounds of Sampling including Colder Weather and Crawlspace Sampling

Recognizing the temporal and spatial variability of indoor air and subsurface concentrations, EPA generally recommends collecting more than one round of sampling and from multiple locations. In reviewing the multiple lines of evidence that have been collected for the South Bay Sites, EPA Region 9 has identified several data gaps that must be filled in order to complete the vapor intrusion evaluations at each site. Specifically, it appears that multiple rounds of indoor air sampling have not been collected. For some sites, sampling has not been conducted during colder weather months, nor have samples been collected from crawlspaces or basements, where such are present in buildings.

Research studies[5678] have demonstrated that daily indoor air concentrations resulting from subsurface vapor intrusion can vary by two or more orders of magnitude in residential, passively ventilated structures. These studies also indicate that the highest indoor air concentrations usually occur when outdoor air temperatures are significantly lower than indoor air temperatures. Empirical indoor air data collected at passively ventilated buildings in the San Francisco Bay Area where multiple samples were collected indicate TCE indoor air concentrations from vapor intrusion up to two-to-three times higher during the colder months.

Work Plans should be revised to incorporate multiple rounds of sampling, including sampling during colder weather months (November through February, with January generally being the coldest month in the Bay Area), to assess the potential variability of indoor air contaminant concentrations during conditions when the potential for vapor intrusion may be higher. In addition, crawlspace, basement, and pathway sampling should be included, as appropriate, as part of the vapor intrusion investigation.

Finally, EPA Region 9 supports the use of longer-term passive samplers to help assess the temporal variability of indoor air vapor intrusion-related contaminant concentrations. The longer-term sampler provides a greater duration over which to average indoor air vapor intrusion levels for the purposes of completing the vapor intrusion evaluation, however EPA Region 9 is open to discussing sampling strategies for both the passive sampler and TO-15 canister.

Item #4 – Commercial Building Sampling Approach - Building Ventilation System (HVAC)-Off, HVAC-On and Pathway Sampling

Consistent with the multiple-lines-of-evidence approach recommended by EPA guidance, ongoing vapor intrusion evaluations at certain commercial buildings associated with some of the South Bay Sites have included soil gas, sub-slab soil gas, and/or potential preferential pathway sampling (such as near bathroom floor drains and from elevator shafts or mechanical rooms), as well as indoor air sampling during normal business hours with the building's heating, ventilation, and air conditioning (HVAC) systems operating.

In reviewing these lines of evidence, EPA Region 9 has identified as a data gap the lack of HVAC-off sampling for certain commercial buildings, and recommends that pathway sampling, where such sampling has not yet been conducted, be included in the multiple-lines-of-evidence evaluation.

Because EPA needs to evaluate the potential for subsurface vapor intrusion into buildings without reliance on the indoor air ventilation system and understand the full range of possible exposure scenarios, Work Plans must be prepared or revised, as appropriate, to include indoor air sampling with the building ventilation systems turned off in addition to sampling commercial buildings under current

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5 Schumacher, B., R. Truesdale, and C. Lutes. Fluctuation of Indoor Radon and VOC Concentrations due to Seasonal Variations. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R/12/673, 2012

6 Schumacher, B. and J. Zimmerman, U.S. EPA ORD, C. Lutes, ARCADIS, and R. Truesdale, RTI International. Indoor Air and Soil Gas Temporal Variability Effects on Sampling Strategies: Evidence from Controlled and Uncontrolled Conditions in an Indianapolis duplex. March 18, 2013 Association for Environmental Health and Sciences Foundation Conference: https://iavi.rti.org/WorkshopsAndConferences.cfm

7 Johnson, P. Arizona State University. Multi-Year Monitoring of a House Over a Dilute CHC Plume: Implications for Pathway Assessment using Indoor Air Sampling and Forced Under-Pressurization Tests. March 18, 2013 Association for Environmental Health and Sciences Foundation Conference: https://iavi.rti.org/WorkshopsAndConferences.cfm

8 Holton, C., H. Luo, Y. Guo, and P. Johnson, Arizona State University, K. Gorder and E. Dettenmaier, Hill Air Force Base. Long-term and Short-term Variation of Indoor Air Concentration at a Vapor Intrusion Study Site. March 22, 2012 Association for Environmental Health and Sciences Foundation Conference: https://iavi.rti.org/WorkshopsAndConferences.cfm

building operating conditions.

For HVAC-off sampling, sampling duration should begin a minimum of 36 hours following shut-down of the building ventilation systems (no outdoor air intakes into the building) and continue while HVAC systems remain off. Because there is a greater potential for elevated indoor air contaminant concentrations while the building ventilation is turned off, adequate notice must be provided to building management and potential occupants about the testing and the schedule for when the ventilation system will be shut off.

Item #5 – On-Property Study Area Building Sampling

At certain of the South Bay Sites, indoor air sampling was originally not required at specific On-Property Study Area (or former source area) commercial buildings that were thought to have a low potential for vapor intrusion (e.g., due to the presence of a vapor intrusion mitigation system such as a sub-floor vapor barrier or where living or workspaces are located above a ventilated underground parking garage).

However, vapor intrusion sampling has shown the potential for vapor intrusion to occur at buildings with existing vapor intrusion mitigation systems (for example, where the systems were damaged during building construction or renovation activities). For buildings overlying subterranean parking garages, preferential pathways such as elevator shafts and stairwells may also increase vapor intrusion potential into occupied living spaces.

EPA Region 9 would like to clarify that all On-Property Study Area buildings should be evaluated and sampled. For building space overlying subterranean parking, potential preferential pathways into the building indoor air space, such as elevator shafts and stairwells, should be evaluated.

Work Plans should be prepared or revised, as appropriate, to include pre-sampling walk-throughs to assess building and system conditions. These building surveys should identify if there are any conditions that may prompt any additional evaluation and sampling to assess the effectiveness of the vapor intrusion engineering controls of the buildings.

Item #6 – Phased Approach and Clarification of Vapor Intrusion Off-Property Study Areas to Include Buildings Overlying 5 μg/L TCE Shallow-Zone Groundwater Contamination

EPA supports the initial agreed upon prioritization of conducting vapor intrusion evaluations at commercial and residential buildings overlying higher TCE shallow A-zone groundwater contamination (greater than 50 μg/L for residential buildings and greater than 100 μg/L for commercial buildings). For those South Bay Sites where vapor intrusion evaluations have already begun, early project planning discussions culminated in a phased approach to delineating the Vapor Intrusion Off-Property Study Area, beginning with investigations in these higher concentration areas of the subsurface groundwater plumes.

The groundwater contamination at the South Bay Sites is generally very shallow, ranging between approximately 5 feet below ground surface (bgs) to 35 feet bgs. Ongoing data collection efforts at other similar vapor intrusion sites in Region 9, as well as nationally, have shown vapor intrusion potential into buildings overlying lower groundwater TCE concentrations (less than 50 μg/L for residential buildings and less than 100 parts μg/L for commercial buildings), at levels exceeding health protective indoor air levels. Factors include, but are not limited to, location relative to source areas, impacts due to seasonal fluctuations in groundwater levels, preferential pathways into a building and other building-specific characteristics that facilitate upward migration of subsurface vapors into interior living and work spaces.

The use of the TCE 5 µg/L groundwater concentration as defining the extent of the Vapor Intrusion Evaluation Study Area is reasonable, supported by use of EPA's vapor intrusion screening level calculator, the generic default groundwater-to-indoor air attenuation factor of 0.001 and the appropriate Henry's Law conversion, empirical data, and mathematical modeling.

Work Plans shall be prepared or revised, as appropriate, to define the Vapor Intrusion Off-Property Study Area as the area bounded by the estimated TCE shallow zone groundwater contamination area greater than 5 µg/L. A comprehensive evaluation of the multiple lines of evidence collected for each site should be used in determining the potential for vapor intrusion at particular buildings and whether additional investigation and response actions are warranted. Any proposal to exclude particular buildings from indoor air sampling must be supported by a robust, site- and building-specific multiple-lines-of-evidence analysis.

Where contaminants other than TCE drive the vapor intrusion investigation, a site-specific and contaminant-specific analysis following the multiple-lines-of-evidence approach should be used to derive a sufficiently health protective study boundary for the vapor intrusion evaluation.

EPA supports a phased multiple-lines-of-evidence approach in prioritizing vapor intrusion investigations, for example: (1) colder weather indoor air sampling event and commercial building HVAC-off and HVAC-on sampling within the original Off-Property Study Area; (2) data evaluation and identification of data gaps, with subsequent additional multiple-lines-of-evidence data collection and analysis; (3) targeted step-out's to specific commercial/residential buildings or streets overlying lower contaminant concentration contour lines; and finally (4) full step-out and building-specific evaluation to off-property vapor intrusion study boundary line, or 5 µg/L for TCE.

EXHIBIT G

EPA ~~###-##-####~~

OSWER FINAL GUIDANCE FOR ASSESSING AND MITIGATING THE VAPOR INTRUSION PATHWAY FROM SUBSURFACE SOURCES TO INDOOR AIR
(EXTERNAL REVIEW DRAFT)

NOTICE

This document is an **EPA External Review Draft**. This information is distributed solely for purpose of pre-dissemination public review. It does not represent an interim or final Agency determination or policy. Do not cite or quote.

U.S. Environmental Protection Agency

Office of Solid Waste and Emergency Response

April 2013

DISCLAIMER

This document presents current technical and policy recommendations of the U.S. Environmental Protection Agency (EPA) based on our current understanding of vapor intrusion into indoor air from subsurface sources. This guidance document does not impose any requirements or obligations on the U.S. Environmental Protection Agency (EPA), the states, or the regulated community. Rather, the sources of authority and requirements for addressing subsurface vapor intrusion are the relevant statutes and regulations. Decisions regarding a particular situation should be made based upon statutory and regulatory authority. EPA decision-makers retain the discretion to adopt or approve approaches on a case-by-case basis that differ from this guidance document, where appropriate, as long as the administrative record supporting its decision provides an adequate basis and reasoned explanation for doing so.

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ACRONYMS AND ABBREVIATIONS

ACH	air changes per hour (air exchanges per hour)
ADT	active depressurization technology
ANSI	American National Standards Institute
ASQ	American Society for Quality
ASTM	American Society for Testing and Materials
ASTSWMO	Association of State and Territorial Solid Waste Management Officials
ATSDR	Agency for Toxic Substances and Disease Registry
BTEX	benzene, toluene, ethylbenzene, xylenes
BWD	block-wall depressurization
CalEPA	California Environmental Protection Agency
CASRN	Chemical Abstracts Service Registry Number
CEI	Community Engagement Initiative
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHC	chlorinated hydrocarbon
CIC	Community Involvement Coordinator
CIO	Chief Information Officer
CIP	community involvement plan
CMS	corrective measures study
CSM	conceptual site model
DNAPL	dense non-aqueous-phase liquid
DoD	U.S. Department of Defense
DoN	U.S. Department of Navy
DQO	data quality objective
DTD	drain-tile depressurization
EI	environmental indicator
EPA	U.S. Environmental Protection Agency
FN	false negative
FP	false positive
FR	Federal Register
FS	feasibility study

FYR	five-year review
HI	Hazard Index
HQ	Hazard Quotient
HVAC	heating, ventilation and air conditioning
IC	institutional control
ICIAP	Institutional Controls Implementation and Assurance Plan
IDLH	immediately dangerous to life or health
ITRC	Interstate Technology and Regulatory Council
LCR	lifetime cancer risk
LEL	lower explosive limit
LEP	limited English proficiency
LNAPL	light non-aqueous-phase liquid
LTS	long-term stewardship
MADEP	Massachusetts Department of Environmental Protection
NAPL	non-aqueous-phase liquid
NAS	National Academy of Sciences
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	No Further Action
NIST	National Institute of Standards and Technology
NPL	National Priorities List
NRC	National Research Council
NYSDOH	New York State Department of Health
O&M	operation and maintenance
OIG	Office of the Inspector General
OSC	on-scene coordinator
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OUST	Office of Underground Storage Tanks
PCE	tetrachloroethene
PEM	preemptive mitigation
PID	photoionization detector
P.E.	Professional Engineer
ppbv	parts per billion by volume

PRP	potentially responsible party
QAPP	quality assurance project plan
QMP	quality management plan
RCRA	Resource Conservation and Recovery Act
RfC	inhalation reference concentration
RFI	RCRA facility investigation
RI	remedial investigation
RML	regional removal management level
ROD	Record of Decision
RPM	remedial project manager
SMD	sub-membrane depressurization
SSD	sub-slab depressurization
TAGA	trace atmospheric gas analyzer
TCE	trichloroethylene
UFP-QAPP	Uniform Federal Policy for Quality Assurance Project Plans
UECA	Uniform Environmental Covenants Act
USPS	U.S. Postal Service
UST	underground storage tank
UU/UE	unlimited use/unlimited exposure
VI	vapor intrusion
VISL	vapor intrusion screening level
VOC	volatile organic compound
VC	vinyl chloride

1.0 INTRODUCTION

This guidance document was prepared by the U.S. Environmental Protection Agency (EPA) through the cooperative efforts of a team of EPA Headquarters and Regional staff, known as the Vapor Intrusion Intra-Agency Workgroup (Workgroup). Drafts of this document were subjected to a comprehensive, consultative peer-input process, which included comments and other contributions from Workgroup members representing several EPA offices and the EPA's Vapor Intrusion Forum.[1] Public comments submitted from 2002 through 2012 and recommendations of the Office of Inspector General (OIG) were considered in developing this guidance document.

This document comprises EPA's final vapor intrusion guidance and is referred to herein as the "Final VI Guidance." It describes a recommended framework for assessing vapor intrusion that relies upon collecting and evaluating multiple lines of evidence to support risk management decisions. It also provides guidance about monitoring and terminating building mitigation systems. Peer-reviewed literature, peer-reviewed technical reports, and other pertinent information that support development or implementation of the Final VI Guidance are cited within.

This introductory section: defines the term "vapor intrusion"; summarizes EPA's statutory authorities to protect human populations from vapor intrusion; summarizes the intended uses of the Final VI Guidance, including the applicability of the guidance to petroleum hydrocarbons and other potentially biodegradable chemicals and to nonresidential buildings; identifies supplemental guidance documents and key technical resources that facilitate consideration of the recommendations in the guidance; provides a concise historical accounting of the development of the guidance; describes how the public was involved in the development of the Final VI Guidance; and provides an overview of the organization of the guidance.

1.1 Definition of Vapor Intrusion

Certain hazardous chemicals that are released into the subsurface as liquids or solids may form hazardous gases (i.e., vapors) that migrate through the vadose zone and eventually enter buildings as a gas[2] by migrating through cracks and gaps in basement floors and walls or foundations, including perforations due to utility conduits and any other openings (e.g., sump pits). Vapor intrusion is the general term given to migration of hazardous vapors from any subsurface contaminant source, such as contaminated soil or groundwater, through the vadose zone and into indoor air. Vapor intrusion can occur in a broad range of land use settings, including residential, commercial, and industrial, and affect buildings with virtually any foundation type (e.g., basement, crawl space(s), or slab on grade). Vapor intrusion is similar to radon intrusion in that mechanisms of subsurface vapor migration and soil gas entry into

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[1] The EPA Vapor Intrusion Forum is an intra-Agency group engaged in sharing information, technical resources, and perspectives pertaining to vapor intrusion assessment and mitigation.

[2] The terms 'gas' and 'vapor' are used inter-changeably in this document. Both refer to a substance in the gaseous state, as distinguished from the liquid or solid state.

buildings are similar for radon and volatile, hazardous chemicals of concern to EPA's programs.[3]

Vapor intrusion is widely recognized as a potentially significant cause of human exposure to "volatile" (i.e., vapor-forming) hazardous chemicals in indoor spaces. When vapor intrusion is significant, concentrations of toxic vapors can accumulate indoors to a point where the health of the occupants (e.g., residents, workers, etc.) in those buildings could be at risk.[4] In addition, methane and certain other volatile chemicals can pose explosion hazards when they accumulate in confined spaces, in addition to the toxicity threats they may pose in occupied spaces.

Section 2.0 describes the vapor intrusion pathway in greater detail.

1.2 Statutory Authorities

Protection of human health is a critical mandate underlying several federal statutes, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended,[5] and the Resource Conservation and Recovery Act (RCRA), as amended.[6] Protection of human health is also a critical objective of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which is the federal government's blueprint for responding to oil spills and releases of hazardous substances, pollutants, or contaminants. On this basis, the EPA has broad authority to assess and, if warranted, mitigate vapor intrusion in residential and nonresidential settings arising from subsurface contamination by hazardous chemicals. If hazardous vapor-forming chemicals are present, the potential for human health risk from vapor intrusion should be evaluated throughout the cleanup life cycle (i.e., initial site assessment, site investigation, interim response actions,[7] final cleanup actions, and periodic reviews of the selected cleanup plan).[8]

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[3] Radon is a colorless, odorless, radioactive gas that is formed from the decay of radium, a radioactive element that occurs naturally in the soil and bedrock in many areas of the United States. Radon can also be emitted from certain uranium- or radium-containing products and wastes.

[4] A recent, registry-based epidemiological study (Forand et al. 2012) reported adverse birth outcomes (including cardiac defects) in areas in Endicott, New York with TCE-contaminated groundwater.

[5] Amendments to CERCLA include the Small Business Liability Relief and Brownfields Revitalization Act.

[6] Application of these statutory authorities to a particular situation generally entails site- and fact-specific analysis. In general, Regions should make decisions about use of these authorities and about intra-Regional coordination of staff and budgetary resources when addressing sites with potential concerns for vapor intrusion.

[7] The words "response action" or "response" are used generically in this guidance to include remedial and removal actions under CERCLA as amended and similar actions under RCRA as amended.

[8] EPA may need access to private property to conduct investigations, studies and cleanups pursuant to CERCLA and RCRA, as amended. The Superfund Amendments and Reauthorization Act of 1986 and RCRA explicitly grant EPA the authority to enter property for these purposes (EPA 1986, 1987, 2010a). EPA generally prefers to obtain access through consent. If consent is denied, however, EPA can use the judicial process or an administrative order to gain access. Application of legal doctrines to a particular access situation requires site- and fact-specific analysis.

1.3 Scope and Applicability of Document

The Final VI Guidance presents EPA's current recommendations for how to identify and consider key factors when assessing vapor intrusion, making risk management decisions, and implementing mitigation pertaining to this potential human exposure pathway. This guidance addresses both residential and nonresidential buildings that may be impacted by vapor intrusion from subsurface contamination.

The Final VI Guidance supersedes and replaces all Agency guidance documents addressing assessment and mitigation of the vapor intrusion pathway, including EPA's *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (EPA 2002c) ("Draft VI Guidance").

The Final VI Guidance is intended for use at any site[9] being evaluated by EPA pursuant to CERCLA or RCRA, EPA's brownfield grantees, or state agencies with delegated authority to implement CERCLA or RCRA where vapor intrusion may be of potential concern. EPA recommends consideration of the Final VI Guidance when:

- Making "Current Human Exposures Under Control" environmental indicator (EI) determinations at RCRA corrective action facilities (EPA 1999a, 2002b)[10] and National Priorities List (NPL) sites under CERCLA (EPA 2008b);
- Undertaking removal actions, remedial actions, pre-remedial investigations,[11] remedial investigations, and five-year reviews (FYRs)[12] under CERCLA; and
- Undertaking RCRA facility investigations and corrective actions and site investigations and cleanups at federal facilities and brownfield sites.

The broad concepts of this guidance generally may be appropriate when evaluating any of a large number and broad range of vapor-forming chemicals— described and identified in Section 3.1 and Appendix A—that potentially can provide subsurface sources for vapor intrusion into buildings. These chemicals include, for example, chlorinated hydrocarbons (CHCs), petroleum hydrocarbons, other types of both halogenated and non-halogenated volatile organic

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[9] The term "site" is used generically in this guidance to represent areas of contamination managed in a cleanup project under CERCLA as amended, under RCRA as amended, at a federal facility, or pursuant to an EPA Brownfields grant.

[10] Also see http://www.epa.gov/osw/hazard/correctiveaction/eis/faqs.htm.

[11] The Hazard Ranking System (HRS) is the statutorily required method for identifying sites for placement on the NPL.

[12] There are additional, special considerations for CERCLA five-year reviews that are described in the companion OSWER Directive 9200.2-84 (EPA 2012d).

compounds (VOCs), elemental mercury, and radon when it arises from uranium- or radium-bearing solid wastes in the subsurface.[13]

This guidance document addresses risk management or exposure mitigation methods for indoor air contamination that arises from vapor intrusion from subsurface sources of these vapor-forming chemicals. It is not intended as a guide for assessing or mitigating indoor air exposures that arise solely from other sources (e.g., indoor use and storage of certain consumer products[14]).

The exposure route of general interest for vapor intrusion is inhalation of toxic vapors present in indoor air that have entered via soil gas entry from the subsurface.[15] Other human exposure routes that may warrant consideration during site investigations of subsurface contamination (e.g., ingestion of soil or water, dermal contact with soil or water, inhalation of particulate material, inhalation of vapors while outdoors, and inhalation of vapors while showering or washing with contaminated groundwater while indoors) are not addressed in this guidance document.

1.3.1 Applicability to Petroleum Hydrocarbons

The broad concepts of this guidance document are generally applicable to petroleum hydrocarbons. In particular, the approaches in the Final VI Guidance are recommended for evaluating the vapor intrusion pathway pursuant to CERCLA and RCRA for petroleum hydrocarbons that are mixed with CHCs or are the result of releases from sources other than Subtitle I underground storage tank (UST) systems. For petroleum hydrocarbons that arise from petroleum that has been released from Subtitle I UST systems, EPA has developed a companion to this Final VI Guidance, which provides information and guidance about how vapor intrusion should be assessed for petroleum hydrocarbons in these settings ("OUST Guidance") (EPA 2013d). The OUST guidance may also be useful in informing decisions about vapor intrusion and petroleum hydrocarbons at brownfield sites that are similar to a typical Subtitle I UST release.

Many petroleum hydrocarbons may naturally biodegrade in the vadose zone through the actions of microorganisms found naturally in soil. When oxygen supply from the atmosphere is sufficient, biodegradation of petroleum hydrocarbons can occur relatively quickly, will generally produce less harmful compounds, and can result in substantial attenuation of petroleum hydrocarbon vapors over relatively short distances in the vadose zone.

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[13] Radon emanating from natural geological materials may impact indoor air quality in occupied buildings. According to EPA estimates, inhalation of toxic radon decay products is the leading cause of lung cancer among non-smokers. For more information and EPA-recommended action levels for radon, see: http://www.epa.gov/radon/healthrisks/html.

[14] Indoor air in most buildings will contain detectable levels of a number of volatile compounds, whether or not the building overlies a subsurface source of vapor-forming chemicals (EPA 2011a). As discussed further in Section 2.5 of this document, these chemicals originate from indoor uses of chemical-containing products and from outdoor (ambient) air. EPA's indoor air quality program provides useful advice for control of indoor air exposures (see http://www.epa.gov/iaq/).

[15] In addition, certain hazardous chemicals (e.g., methane) can pose explosion hazards when they accumulate in confined spaces.

Numerous site-specific factors can influence the biodegradation rate of petroleum hydrocarbons and other biodegradable vapor-forming chemicals in the vadose zone. These factors include quantities, distribution, types, and mixtures of vapor-forming chemicals, which can differ substantially among sites where petroleum hydrocarbons are released to the subsurface environment. The Final VI Guidance allows site-specific observations of the effects of biodegradation to be considered in its approach for petroleum hydrocarbons (and any other biodegradable, vapor-forming chemical).

1.3.2 Applicability to Nonresidential Buildings

EPA's statutory authorities to protect human health (see Section 1.2) include mandates to protect the public and workers' health in nonresidential settings where hazardous vapors may be intruding into occupied buildings from vapor intrusion. As used in the Final VI Guidance, the phrase "nonresidential buildings" may include, but is not limited, to institutional buildings (e.g., schools, libraries, and hospitals); commercial buildings (e.g., hotels, office buildings, and retail establishments); and industrial buildings where vapor-forming chemicals may or may not be routinely used or stored.

Section 4.0 expands on EPA's recommended approach to evaluating and mitigating vapor intrusion in nonresidential buildings.

1.4 Additional Companion Documents and Technical Resources

Supplemental guides and technical support documents were developed to facilitate consideration of the recommendations in the Final VI Guidance. They are described in this section and can be found on OSWER's website about vapor intrusion (see Section 10.0 for citations and Web links).

1.4.1 Vapor Intrusion Screening Level Calculator

The Vapor Intrusion Screening Level (VISL) Calculator (2012c) is a recommended spreadsheet that:

(1) Identifies chemicals considered to be typically vapor-forming and known to pose a potential cancer risk or noncancer hazard through the inhalation pathway;

(2) Provides generally recommended screening-level concentrations for groundwater, near-source soil gas (exterior to buildings), sub-slab soil gas, and indoor air based upon default residential or nonresidential exposure scenarios, a target cancer risk level of one per million (10^{-6}), and a target hazard quotient of one for potential non-cancer effects; and

(3) Facilitates calculation of site-specific screening levels based on user-defined target risk levels, exposure scenarios, and semi-site-specific attenuation factors.

The VISL Calculator can be used in evaluating whether the vapor intrusion pathway has the potential to pose a health concern by helping to:

(1) Identify whether chemicals that can pose a risk through vapor intrusion are present;

(2) Determine if those chemicals are potentially present at explosive levels;

(3) Compare subsurface or indoor data against recommended screening levels provided in the VISL Calculator; and

(4) Prioritize buildings and sites for investigation and response action.

The recommended screening-level concentrations in the spreadsheet are calculated using the recommended approaches in existing EPA health risk assessment guidance and are based on current understanding of the vapor intrusion pathway. EPA intends to periodically update the VISL Calculator to incorporate new toxicity or chemical property information that becomes available.

1.4.2 Superfund Five-year Review Guidance

Section 121 of CERCLA requires that remedial actions that result in any hazardous substances, pollutants, or contaminants remaining at the site be re-evaluated every five years to ensure that the remedy is and will continue to be protective of human health and the environment. OSWER Directive 9200.2-84 (*Assessing Protectiveness at Sites for Vapor Intrusion: Supplemental Guidance to the Comprehensive Five-Year Review Guidance* (EPA 2012d)) provides a recommended framework for considering vapor intrusion while evaluating remedy protectiveness in the context of the Superfund FYR process (even if vapor intrusion was not addressed as part of the original remedial action).

1.4.3 Technical Support Documents

Technical information pertaining to vapor intrusion has also been prepared to support development of the technical approaches and policy recommendations in the Final VI Guidance and OUST Guidance. Key supporting documents include:

<u>*Background Indoor Air Concentrations of Volatile Organic Compounds in North American Residences (1990-2005): A Compilation of Statistics for Assessing Vapor Intrusion* (EPA 2011a)</u>: This externally peer-reviewed, technical report presents (1) a summary of indoor air studies that measured background concentrations of VOCs in the indoor air of thousands of North American residences and an evaluation and (2) compilation of the statistical information reported in these studies. The objective of this compilation is to illustrate the ranges and variability of VOC concentrations in indoor air during the study period (1990-2005), resulting from sources other than vapor intrusion.

<u>*EPA's Vapor Intrusion Database: Evaluation and Characterization of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings* (EPA 2012a)</u>: This externally peer-reviewed report presents technical information about sites in the U.S. that have been investigated for vapor intrusion. The primary focus of the report is the evaluation of concentrations of chlorinated VOCs in and underneath residential buildings based upon the EPA's vapor intrusion database as of 2010. This report provides the technical basis for

the generic and semi-site-specific attenuation factors recommended in the Final VI Guidance to calculate vapor intrusion screening levels (see Section 6.5 and Appendix B).

Conceptual Model Scenarios for the Vapor Intrusion Pathway (EPA 2012b): This externally peer-reviewed report provides simplified simulation examples to illustrate graphically how subsurface conditions and building-specific characteristics determine: (1) the distribution of vapor-forming chemicals in the subsurface; and (2) the indoor air concentration relative to a source concentration. It was prepared to help environmental practitioners gain insights into the processes and variables involved in the vapor intrusion pathway and to provide a theoretical framework with which to draw inferences about and better understand the complex vapor fate and transport conditions typically encountered at actual, contaminated sites.

Sampling and Analysis Methods for Vapor Intrusion Investigations (EPA 2013c): This report provides a technical description of the most commonly implemented and generally accepted techniques for collecting samples of indoor air, outdoor air, soil gas or sub-slab gas for analysis of VOCs or other vapor-forming chemicals that might be of concern for the vapor intrusion pathway. It was prepared to assist site managers and risk assessors select the most appropriate sampling devices and analytical methods to employ during site-specific investigations.

Technical Basis for the Selection, Design, Installation and Operation & Maintenance of Vapor Intrusion Mitigation Systems (EPA 2013b): This report provides a technical description of the most commonly implemented and generally accepted methods for mitigation of vapor intrusion in buildings and provides information about their design and construction.

All of these tools and documents, as well as others, can be found at http://www.epa.gov/oswer/vaporintrusion, a website developed to support the development of the Final VI Guidance and enhance public communication about the topic. This website also allows certain sections of this guidance to be more dynamic and facilitates updates to information.

Technical documents intended to facilitate consideration of the recommendations in the OUST Guidance can be found at http://www.epa.gov/oust/cat/pvi/.

1.5 Historical Context

To help assess the subsurface vapor intrusion pathway, the Office of Solid Waste and Emergency Response (OSWER) released in November 2002 for comment EPA's Draft VI Guidance, which presents EPA's technical and policy recommendations for evaluating subsurface vapor intrusion, based on the understanding of vapor intrusion at that time (EPA 2002c). The Final VI Guidance supersedes and replaces the Draft VI Guidance.

Since the Draft VI Guidance was released, EPA's knowledge of and experience with assessment and mitigation of the vapor intrusion pathway has increased considerably, leading to an improved understanding of and enhanced approaches for evaluating and managing vapor intrusion. In December 2009, the OIG made recommendations regarding EPA's Draft VI

Guidance, which are documented in the evaluation report *Lack of Final Guidance on Vapor Intrusion Impedes Efforts to Address Indoor Air Risks* (Report No. 10-P-042; EPA 2009a). Among other things, the OIG recommended that the final guidance incorporate:

- Updated toxicity values.
- A recommendation(s) to use multiple lines of evidence in evaluating and making decisions about risks from vapor intrusion.
- How risks from petroleum hydrocarbon vapors should be addressed.
- How the guidance applies to Superfund FYRs.
- When or whether preemptive mitigation is appropriate.
- Operations, maintenance, and termination of mitigation systems.
- When institutional controls (ICs) and deed restrictions are appropriate.

In its response letter dated March 11, 2010, OSWER generally agreed with OIG's recommendations to finalize guidance on vapor intrusion. In addition, the OIG recommended that EPA identify and publicly report the portions of its Draft VI Guidance that remain valid and the portions that should be updated.[16]

The Final VI Guidance and the companion documents identified in Sections 1.3 and 1.4 fulfill EPA's commitment to issue final vapor intrusion guidance that addresses all of OIG's recommendations. Table 1-1 identifies specific guidance updates prepared by EPA in response to OIG's specific recommendations. Table 1-2 describes additional guidance updates identified and publicly announced by EPA (EPA 2010b).

[16] OSWER carried out this recommendation by issuing a memorandum in August 2010 (EPA 2010b), a copy of which is included on OSWER's vapor intrusion website at http://www.epa.gov/oswer/vaporintrusion/documents/review_of_2002_draft_vi_guidance_final.pdf. The guidance reflected in this memorandum is incorporated in the Final VI Guidance.

TABLE 1-1
DIRECTORY TO UPDATES IN EPA'S FINAL VAPOR INTRUSION GUIDANCE ADDRESSING RECOMMENDATIONS OF EPA OFFICE OF INSPECTOR GENERAL (EPA 2009)

Topics to Be Addressed	Location Within This Guidance Document	Companion Document(s)
Update toxicity values		*VISL Calculator* (EPA 2012c)
Use of multiple lines of evidence in evaluating and making decisions about risks from vapor intrusion	Sections 2, 5, and 6	
How risks from petroleum hydrocarbon vapors should be addressed	Section 1.3.1	*Guidance for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites* (EPA 2013d)
How the guidance applies to Superfund FYRs		*Assessing Protectiveness at Sites for Vapor Intrusion: Supplemental Guidance to the Comprehensive Five-Year Review Guidance* (EPA 2012d)
When or whether preemptive mitigation/early action is appropriate	Sections 3.4 and 9.0	
Operations and maintenance of mitigation systems	Section 8.3	
Termination of mitigation systems	Section 8.7	
When ICs and deed restrictions are appropriate.	Section 8.6	

TABLE 1-2
DIRECTORY TO ADDITIONAL UPDATES IN EPA'S FINAL VAPOR INTRUSION GUIDANCE PUBLICLY IDENTIFIED BY OSWER (EPA 2010A)

Topics to Be Updated, Including References to the Draft VI Guidance	Location Within This Guidance Document	Companion Document(s)
Updated a few chemical-specific physical parameters used for identifying the vapor-forming chemicals of concern.	Appendix A	VISL Calculator (EPA 2012c)
Updated the toxicity-based criteria in Table D-1 in the draft guidance.	Appendix A	VISL Calculator (EPA 2012c)
Observation-based conservative attenuation factors have been updated with a larger database. The generic attenuation factor for external soil gas has been updated, as well as the Reliability Assessment, using the newer available data.	Section 6.5.2 and Appendix B	*U.S. EPA's Vapor Intrusion Database: Evaluation of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings* (EPA 2012a)
Observational data since 2002 indicates that the "single line of evidence" approach with site-estimated attenuation factors is generally not appropriate for external soil gas samples.	Section 6.4.4 and Appendix B	*Sampling and Analysis Methods for Vapor Intrusion Investigations* (EPA 2013c)
Experiences since 2002 illustrate the value of collecting indoor air samples earlier in the investigations. The "indoor lair last" approach has been updated that will allow more flexibility in the sequencing of subsurface and interior/indoor sample collection.	Sections 6.3.4 and 6.3.6	
The portions addressing background contamination has been updated. EPA also updated with more specific methodologies for evaluating and/or decision-making and managing background contamination.	Section 6.3.5	
The portion of the guidance focusing on testing indoor air has been updated to allow more flexibility in the duration of sampling to take advantage of other sampling durations and methods.	Section 6.4.1	*Sampling and Analysis Methods for Vapor Intrusion Investigations* (EPA 2013c)
The Draft VI Guidance allows site-specific decisions to be made based on indoor air concentrations in a relatively few representative buildings. This portion of the guidance has been updated to increase the confidence that the approach fully addresses building-by-building variability.	Section 9	
Updated and expanded the community involvement guidance to be more specific to vapor intrusion sites, including guidelines for effective risk communication and available resources, outreach products and tools for outreach.	Section 10	

Since EPA's release of its Draft VI Guidance in 2002, other federal agencies with responsibilities and obligations for environmental cleanup or for response to reports of vapor intrusion (e.g., ATSDR 2008; DoD 2009; DoN 2011a; USPS 2009) have developed vapor intrusion guides for their respective programs. In addition:

- A number of state agencies involved with environmental quality or public health protection have developed vapor intrusion guides for their programs, which they may continue to implement under their respective statutory authorities (e.g., see ASTSWMO [2009], a compilation).

- The Interstate Technology & Regulatory Council (ITRC), a state-led coalition of environmental regulatory professionals, prepared a two-volume guideline for assessing the vapor intrusion pathway (ITRC 2007ab).

EPA has considered these guides in developing the Final VI Guidance. EPA believes that States will find the Final VI Guidance useful.

1.6 Public Involvement in Developing Vapor Intrusion Guidance

On November 29, 2002, EPA published a notice in the *Federal Register* (67 FR 71169) announcing and soliciting comment on its Draft VI Guidance. Over the next decade, EPA continued to gather information and learn more about vapor intrusion, in part by convening periodic forums where practitioners, regulated parties, and regulators could discuss the emerging science and engineering pertaining to vapor intrusion assessment and mitigation. In addition, on March 17, 2011, EPA published a notice in the *Federal Register* (76 FR 14660) re-opening the docket and soliciting additional comment on its development efforts for the Final VI Guidance. The docket was re-opened again in March 2012 to receive comments about specific technical documents that were prepared to support development of this guidance document; these technical documents are listed in Section 1.4. In developing the Final VI Guidance, EPA considered all public comments and input received during the past decade.

EPA also decided to proactively engage communities beyond the traditional outreach practices, especially environmental justice communities and communities subject to multiple stressors.[17] Aspects of this engagement have included:

- Conducting public listening sessions in communities impacted by vapor intrusion to solicit input on developing the Final VI Guidance.

- Using Internet sites and other communication tools to update stakeholders on the progress of developing the Final VI Guidance.

Table 1-3 identifies specific vapor intrusion topics that have received substantive public comment as a result of EPA's outreach efforts.

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[17] For more information about the Community Engagement Initiative visit: http://www.epa.gov/oswer/engagementinitiative/

TABLE 1-3
VAPOR INTRUSION TOPICS RECEIVING SUBSTANTIVE PUBLIC COMMENT

Topics	Location Within This Guidance Document	Companion Document(s)
Applicability to petroleum hydrocarbons	Section 1.3.1	*Guidance for Addressing Petroleum Vapor Intrusion at Leaking Underground Storage Tank Sites* (EPA 2013d)
Applicability to nonresidential buildings	Sections 1.3.2 and 4.0	
Conditions warranting prompt action and short-term response actions	Sections 5.2 and 8.2.1	
Planning investigations and applying data quality objectives	Section 6.2 and Appendix C	
Sampling and monitoring methods for indoor air	Section 6.4.1	*Sampling and Analysis Methods for Vapor Intrusion Investigations* (EPA 2013c)
Attenuation factors and risk-based screening	Section 6.5 and Appendix B	*U.S. EPA's Vapor Intrusion Database: Evaluation of Attenuation Factors for Chlorinated Volatile Organic Compounds and Residential Buildings* (EPA 2012c)
Semi-site-specific screening and application of mathematical models	Sections 6.5 and 6.6	
Use of conceptual site models and multiple lines of evidence in evaluating risks posed by vapor intrusion	Sections 2, 5.4, 6.3, and 7	
Use of institutional controls for building mitigation	Section 8.6	
Monitoring and termination of mitigation systems	Sections 8.4 and 8.7	
Risk communication	Section 10	

1.7 Organization

The next nine sections of this guidance document are as follows:

- Section 2.0 Conceptual Model of Vapor Intrusion further describes vapor intrusion and identifies many of the variables that influence vapor migration in the vadose zone and soil gas entry into buildings.

- Section 3.0 Overview of Vapor Intrusion Guide provides an overview of this guidance document and the general framework of the vapor intrusion assessment and mitigation process.

- Section 4.0 Considerations for Nonresidential Buildings provides guidance regarding EPA roles, responsibilities, and risk management decision-making in workplace settings, including those (e.g., manufacturing facilities) where workers handle hazardous chemicals similar to or different from those contaminating the subsurface.

- Section 5.0 Preliminary Analysis of Vapor Intrusion provides technical and policy guidance for situations where only limited site-specific sampling data may be available (e.g., initial site assessment).

- Section 6.0 Detailed Investigation of Vapor Intrusion provides technical and policy guidance for conducting site-specific vapor intrusion assessments emphasizing multiple lines of evidence.

- Section 7.0 Risk Management Framework provides general recommendations about risk-informed decision-making pertaining to vapor intrusion.

- Section 8.0 Building Mitigation and Subsurface Remediation provides technical and policy guidance for mitigating vapor intrusion and describes how subsurface vapor source remediation and other final cleanup actions are combined with engineering exposure controls to ensure protection of human health.

- Section 9.0 Preemptive Mitigation/Early Action discusses statutes and considerations affecting the selection and implementation of building mitigation as an early action for vapor intrusion.

- Section 10.0 Planning Guide for Community Involvement provides guidance and describes available resources for engaging affected communities and communicating risk-related information.

This guidance document concludes with Section 11.0, Citations and References, and four supporting appendices:

- Appendix A: Chemicals of Potential Concern for Vapor Intrusion.

- Appendix B: Generic Attenuation Factors Used to Develop Screening Levels.

- Appendix C: Data Quality Assurance Considerations.
- Appendix D: Calculating Vapor Source Concentration from Groundwater Data.

2.0 CONCEPTUAL MODEL OF VAPOR INTRUSION

This section presents a conceptual model of vapor intrusion, borrowing from published depictions (EPA 2008a; EPA 2012b; ITRC 2007a; McAlary et al. 2011; DoD 2009). It identifies and describes many of the lines of evidence pertinent to evaluating vapor intrusion.[18] It concludes with several general observations that may assist practitioners when conducting detailed vapor intrusion investigations.

Vapor intrusion is a potential human exposure pathway – a way that people may come into contact with environmental contaminants while performing their day-to-day indoor activities. Figure 2-1 summarizes the vapor intrusion pathway.

The exposure route of general interest for vapor intrusion is inhalation of toxic vapors present in indoor air. As noted previously, methane and certain other volatile chemicals can also pose explosion hazards when they accumulate in confined spaces.

Three conditions must exist for hazardous vapors to reach the interior of buildings from the subsurface environment underneath or near a building:

1. A source of hazardous vapors must be present in the soil or in groundwater underneath or near a building.
2. Vapors must form and have a pathway along which to migrate toward the building.
3. Entry routes must exist for the vapors to enter the building and driving forces must exist to draw the vapors into the building.

If these three conditions are present, the vapor intrusion pathway is referred to as "complete." These three conditions are further discussed in the next three subsections. Practitioners are encouraged to refer to quantitative discussions of these subjects, which are provided in the user's guide to the Johnson & Ettinger model (EPA 2013e) and *Conceptual Model Scenarios for the Vapor Intrusion Pathway* (EPA 2012b).

Knowledge of potential vapor sources and vapor fate and transport mechanisms is essential for interpreting the data collected during a site-specific investigation of vapor intrusion. Knowledge of the factors that influence the vapor intrusion pathway is also invaluable for identifying, prioritizing, and sequencing data collection activities, which allows a phased and efficient overall investigation plan to be developed.

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[18] In general, a conceptual site model integrates all lines of site-specific evidence into a three-dimensional conceptualization of site conditions that includes contaminant sources, release mechanisms, vapor migration pathways, and potential receptors. Section 5.4 provides additional information about developing conceptual site models.

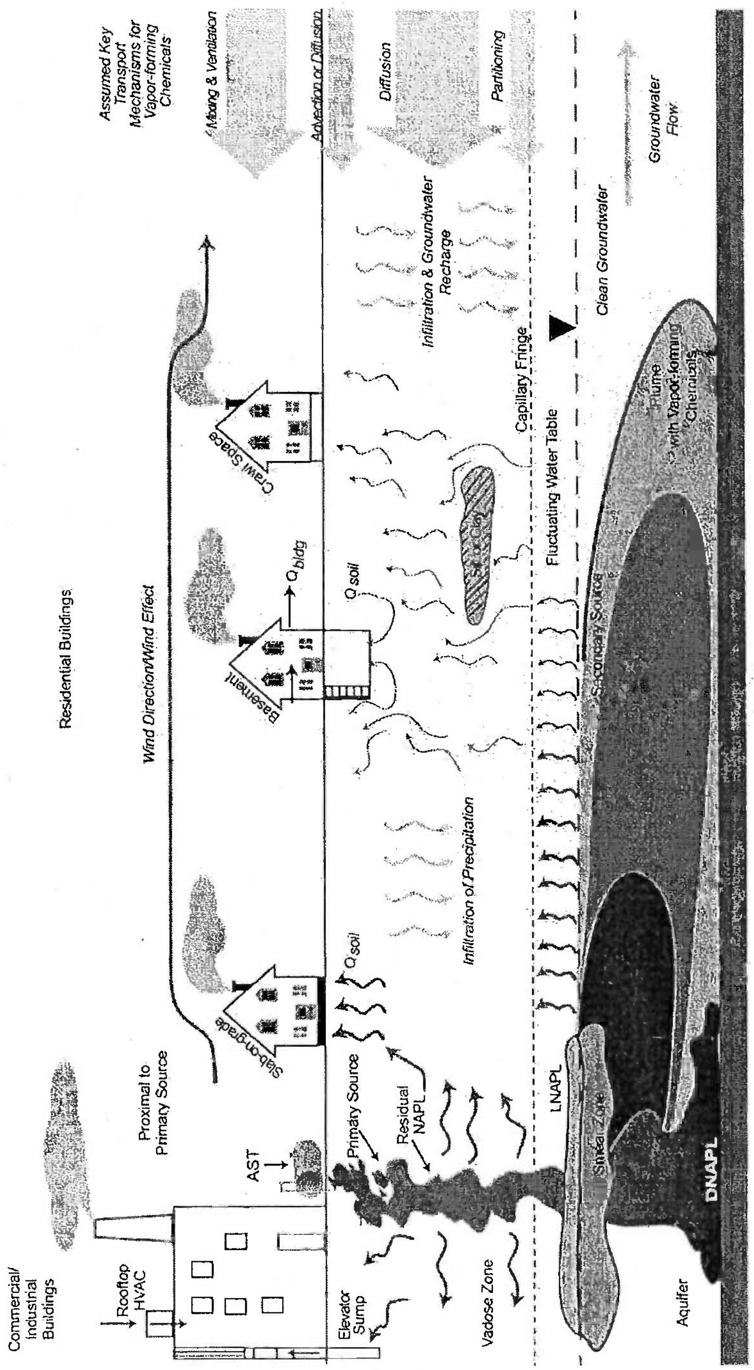

Figure 2-1 Illustration of Conceptual Model of Vapor Intrusion

Note: Q_{soil} represents soil gas entry; Q_{bldg} represents building ventilation.

The human populations of primary interest are individuals living or working in, or otherwise occupying a building subject to vapor intrusion. All types of buildings are potentially vulnerable to vapor intrusion. This includes residential buildings (e.g., single-family homes, trailers, multi-unit apartments and condominiums), commercial workplaces (e.g., office buildings, retail establishments), industrial facilities (e.g., manufacturing plants), and educational and recreational buildings (e.g., schools and gyms). Vapor intrusion can occur in buildings with any foundation type (e.g., basement, crawl space, slab-on-grade).

At sites with existing buildings, there are concerns about whether vapor intrusion may pose an unacceptable health risk to current occupants or potential for explosion hazard. EPA recommends that vapor intrusion should also be evaluated for reasonably expected future land use conditions, including new building construction and new uses and occupants for the uninhabited buildings.

2.1 Subsurface Vapor Sources

The original source(s) of subsurface contamination may include leaking tanks (above or below ground), sewer lines[19] and pipelines, floor drains, landfills and other land disposal management units,[20] fire-training areas, spills, and discharge areas. The resulting subsurface contamination may be comprised of non-aqueous-phase liquids (NAPLs) (e.g., solvents, petroleum-related products, such as gasoline) and contaminated soil. These are often referred to as the source zone(s). In addition, primary vapor releases from pipelines leaking chemical vapors can serve as a source of contamination. Groundwater flowing through the source zone(s) can become contaminated, migrate away, and in turn become a (secondary or derivative) source of contaminant vapors at locations distant from the source zone.

Regardless of source type, soil vapor concentrations emanating from a subsurface source attenuate, or decrease, as the volatile chemicals move from the source through the soil and into indoor air. If soil vapor monitoring data at a given site are not consistent with this trend, practitioners should consider the possible existence of multiple sources at the site and the possibility of bias or error in the sampling techniques.

Contaminants in soil, NAPLs, and groundwater can become sources for vapor intrusion if they are likely to volatilize under normal temperature and pressure conditions and are toxic when inhaled. Water solubility is also a factor for chemicals in source zones that come into contact with migrating groundwater. Common classes of chemicals of concern for vapor intrusion that exhibit the foregoing characteristics are VOCs, such as tetrachloroethene (PCE), trichloroethene (TCE), vinyl chloride (VC), carbon tetrachloride, and benzene, toluene,

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[19] Historically, sanitary sewers and septic tanks have been common disposal points for aqueous and chemical wastes from commercial and industrial operations. Contaminated water, NAPL, and VOC vapors can leak from sewer lines through cracks, joints, or breaks. A study of solvent contamination in California arising from dry cleaning operations concluded, "Where a source investigation has been done in connection with PCE contamination, the ... data strongly indicate that leakage through the sewer lines is the major avenue through which PCE is introduced to the subsurface." (Izzo 1992).

[20] EPA has also published *Guidance for Evaluating Landfill Gas Emissions from Closed or Abandoned Facilities* (EPA 2005), which provides procedures and a set of tools for evaluating landfill gas emissions to ambient air and soil gas migration due to pressure gradients.

ethylbenzene and xylenes (collectively, BTEX). Other compounds that are not as volatile, but that may be cause for concern, are some polychlorinated biphenyl congeners and elemental mercury, a dense NAPL (DNAPL).

Landfill gases, such as methane and hydrogen sulfide, also can be associated with the vapor intrusion pathway for buildings located near current or former landfills or other degrading wastes or near degrading petroleum leaked from USTs. These gases are actively produced as a result of biodegradation processes. Methane can also be associated with the vapor intrusion pathway for buildings located near leaks from underground transmission lines for natural gas.

Properties with potential contamination by vapor-forming chemicals can be found in many industrial and commercial areas. These properties include current and former manufacturing and chemical processing plants, warehouses, landfills and other land disposal units, coal gasification plants, chemical handling or transfer facilities and areas (e.g., train yards), dry cleaners, and retail fueling outlets (also known as gas stations). Use, storage, or transport of chemicals at these facilities may have resulted in a release of vapor-forming chemicals to the environment creating the potential for future vapor intrusion issues. In addition to industrial and commercial activities, roadside dumping, pesticide spraying, or even disposal of household chemicals via a septic field may also release volatile contaminants to the subsurface environment.

The primary contamination source need not, however, be on the property of interest to pose a vapor intrusion problem.[21] The primary source(s) of vapor intrusion (e.g., contaminated soil, or buried drums) may be present on a neighboring property or on a property some distance away. Even "greenspace" properties that have not previously been occupied or developed may contain contamination by vapor-forming chemicals due to migrating plumes of contaminated groundwater or migrating soil gas. Therefore, EPA recommends that the potential for vapor intrusion be considered at all properties being considered for redevelopment or proximate to industrial and commercial use areas (EPA 2008a).

2.2 Subsurface Vapor Migration

At many sites, the vapor source in soil or groundwater is not in contact with the bottom of the subject building. Under these circumstances, a volatile chemical that is present in a source zone or groundwater must volatilize from the source medium and enter the pore space around and between the subsurface soil particles in the soil column above the groundwater table, which is called the unsaturated soil zone or vadose zone. If the vapor source is in the vadose zone, the vapors have the potential to migrate radially in all directions from the source via diffusion (i.e., upward toward the atmosphere, laterally outward, and downward toward the water table, which may eventually lead to groundwater contamination). Diffusion, which is caused by the random motion of molecules, affects the distribution of soil vapors when there are spatial differences in

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[21] Depending on the geology and amount and form of contamination in the source zone(s), contaminated groundwater plumes can be long and narrow and can flow beneath a property located a mile or more away from the primary source. Soil gas plumes tend to extend in both lateral directions and can be larger in lateral extent relative to groundwater plumes.

chemical concentrations in the soil gas. The net direction of diffusive transport is toward the direction of lower concentrations.

Advection occurs in the vadose zone when there is bulk movement of soil gas induced by spatial differences in soil gas pressure. The direction of advective vapor transport is always toward the direction of lower air pressure. Advection is generally expected to occur in the vicinity of buildings, because differences in temperature between the building interior and the subsurface environment or the operation of combustion units or fans within the building can create driving forces for soil gas entry (See Section 2.3). Advection may also occur near the ground surface due to fluctuations in barometric (atmospheric) pressure, which can either release soil gas into the atmosphere or introduce ambient air into the subsurface environment; the latter process may be important in oxygenating surface soil horizons. Advection may be hindered where extensive surface barriers, such as asphalt, concrete, or frozen soil are present.

Vapors also can migrate via advection (and diffusion) along a preferential subsurface pathway, such as a utility corridor or more porous layers of soil, or beneath surface barriers that limit the direction(s) of vapor migration, such as frozen ground or asphalt.

Vapor migration in the vadose zone can be impeded by several factors, including high soil moisture, low-permeability (generally fine-grained) soil, and biodegradation:

- High moisture levels in the vadose zone can significantly reduce the effective rate of diffusive transport, owing to the substantially smaller diffusion coefficient of vapor-forming chemicals in water compared to air. Where impervious ground covers are absent, soil cores taken external to building structures can reasonably be expected to show greater soil moisture than underneath buildings, particularly after episodes of precipitation and infiltration. Fluctuations in the elevation of the groundwater table can also contribute to temporal changes in soil moisture profiles, in addition to changing the thickness of the vadose zone.

- A low-permeability layer in the vadose zone, particularly one with high moisture content or perched water, may impede or prevent upward migration of vapors from deeper sources in the vadose zone.[22] In some cases, soil or rock can impose sufficient resistance to vapor migration to make the vapor intrusion pathway insignificant, providing the geologic features are laterally extensive over distances that are large compared to the size of the building(s) or the extent of subsurface contamination with vapor-forming chemicals.

- Some biodegradable chemicals may experience reductions in their vapor concentrations in biologically active vadose zones. In some cases, biodegradation may make the vapor intrusion pathway insignificant. Depending upon the potential for oxygen to migrate into the subsurface from the ambient air, such biodegradation may be anaerobic or aerobic.

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[22] Low-permeability layer(s) overlying contaminated groundwater (i.e., "aquicludes") can, likewise, impede the flux of vapors from the contaminated plume to the vadose zone. The aquiclude shown at the base of Figure 2-1 would not impede the flux of vapors from the contaminated plume to the vadose zone, however, because the aquiclude is below both. It would impede vapor flux from any additional contaminated plume located below it.

There is uncertainty regarding whether and to what extent oxygen levels will typically be different underneath a building compared to locations outside the building footprint where impervious covers are absent and the ground surface is in contact with the atmosphere. Significant characterization of the soil may, therefore, be required to demonstrate the extent, if any, to which these processes act as a barrier to vapor transport at specific sites, which may entail intensive testing or investigative methods that are very different from the sampling and analysis techniques for indoor air and soil gas. Such characterization should also consider the possibility that biodegradation may result in the formation of by-products that are potentially hazardous (e.g., methane, vinyl chloride from PCE or TCE).

If the vapor-forming chemicals are dissolved in groundwater at the groundwater table (i.e., volatile chemicals are in the uppermost reaches of an unconfined – "water table" – aquifer), fluctuations in the water table will tend to transport the volatile chemicals upward (during periods of rising water table) or expose impacted water above the water table to soil gas (during periods of falling water table). The latter will facilitate the episodic formation of vapors in the vadose zone. Rising water tables also will bring the vapor source closer to the building(s).

If vapor-forming chemicals are not present in the upper reaches of the groundwater table (e.g., due to the presence of an overlying zone of clean water from recharge; i.e., "fresh water lens"),[23] vapor transport to the overlying vadose zone will be impeded due to the slower diffusion of volatile chemicals in water than in soil gas.

2.3 Driving Forces and Entry Routes into Buildings

The distribution and magnitude of vapor concentrations immediately beneath a building are expected to reflect the interplay between vapor transport toward the building (via diffusion and advection) in the vadose zone and vapor withdrawal due to soil gas entry into the building (in the case where the building is under-pressurized), which may be spatially and temporally variable. Likewise, soil vapor may become contaminated as a result of over-pressurized buildings forcing contaminated indoor air through openings in the foundation into nearby soil.

As mentioned in Section 2.2, advection in the vadose zone can arise in the vicinity of buildings whenever there is a differential between the air pressure within a building and the subsurface environment. The air pressure within a building can be lower (or higher) than in the subsurface due to:

- Temperature differences between indoor and subsurface locations (e.g., the winter-time "stack effect," when buildings are commonly heated, leading to convection cells driven

[23] Infiltrating precipitation is important in recharging aquifers with fresh water, as well as in wetting vadose zone soils. At locations distant from "source zones," infiltrated water that reaches the upper surface of a plume of contaminated groundwater (i.e., recharges groundwater) in an unconfined aquifer will tend to dilute concentrations of vapor-forming substances and form a lens of relatively "clean" water at the groundwater table, which will overlie the plume. Because diffusion of dissolved-phase volatile chemicals will tend to control the mass transfer of vapors into the soil gas at the groundwater table, the presence of a lens of clean water overlying a plume will tend to impede vapor flux to the vadose zone. This condition is less likely to occur where fluctuations of the groundwater table are large, relative to local recharge, and would not generally be expected in arid climates.

by heated air that rises to upper levels and leaks through roofs and upper-floor windows).

- The operation of mechanical devices, such as exhaust fans for ventilation, air conditioners, and clothes dryers, with vents to the outdoors.
- The operation of combustion devices that vent exhaust gases to the outside, such as fireplaces and furnaces.
- Wind load on the building walls.

Even small pressure differentials may cause advective flow of gas into or out of the building through pores, cracks, or openings in the building floor or basement walls.[24]

There also may be preferential soil gas flow through granular fill underneath a building, especially in locations where the gas permeability of the surrounding soil is low. Where granular materials have differentially settled, air voids (also highly permeable to soil gas flow) may form beneath the foundation. Utility penetrations and other conduits may be connected to the granular fill, accentuating the potential pathway for soil gas entry into a building. Adding to the complexity, pressure differentials caused by wind flows conceivably could create a cross-flow underneath the foundation, particularly where granular fill is also present underneath a building, which may episodically dilute vapor concentrations in the building vicinity.

Several factors can influence the potential indoor air concentration arising from vapor intrusion. Building ventilation, whether mechanical or natural, may serve to reduce the indoor air concentrations arising from vapor intrusion.[25] Mechanical ventilation may be provided by attic and other exhaust fans or, in the case of larger (e.g., commercial or industrial) buildings, heating or cooling systems that draw outdoor air into the building. Natural ventilation may occur through open windows, doors and attics, openings along the perimeters of windows and doors, and cracks in walls and ceilings.

In buildings that are mechanically ventilated, vapors intruding from the subsurface will tend to be distributed and mixed throughout the indoor air. Mixing can be expected to be incomplete as a general rule. For example, rooms with perforations through the foundation (e.g., bathrooms or utility rooms) tend to have greater concentrations of vapor-forming chemicals in air compared to

[24] As a result of the construction of foundation walls and floor slabs, a perimeter crack (i.e., space between the floor slab and walls) may be created and serve as an entry location for soil vapors. This perimeter crack is often obscured by wall coverings, and may not be accessible for inspection or direct testing. Vapors have been observed to migrate through what appears to be intact concrete floors and walls, which may, in fact, have small unobserved fractures or porous areas from improper curing. In addition, conduits may be present to facilitate soil gas entry into buildings. These conduits may include utility (e.g., sewer, water, or electrical) penetrations and floor drains, which can be considered preferential (structural) pathways. Although floor drains are designed to allow water to drain away from the building, they are usually not designed or constructed to eliminate soil gas entry.

[25] Ventilation is usually described in terms of air exchanges (or changes) per hour (ACH). Values for residential air exchange rates are typically on the order of approximately 0.18 to 1.26 ACH (EPA 2011b, see Table 19-24 therein, 10th and 90th percentiles). Values for non-residential buildings are highly-dependent upon building use and can range widely (on the order of approximately 0.3 to 4.1 ACH) (EPA 2011b, see Table 19-27 therein, 10th and 90th percentiles).

rooms that do not. Generally, basements can reasonably be expected to exhibit greater vapor concentrations than upper occupied levels.

Buildings constructed over a crawl space with a dirt floor may benefit from the dilution of soil gas by any ventilation of crawl space air, but would not have the impedance to vapor intrusion that concrete slabs can provide. Trailers enclosed at the bottom by a skirt are expected to have greater potential for vapor intrusion than would non-enclosed trailers. Wind movement between the ground surface and the bottom of the non-enclosed trailer would tend to minimize vapor buildup and associated potential for vapor intrusion. Similarly, the existence of underground parking for a multi-story building (or other modifications to the foundation that enhance subsurface ventilation) would tend to minimize the potential for vapor intrusion and should be considered in the vapor intrusion evaluation.

2.4 Conceptual Model Scenarios

Based upon the foregoing conceptual model, numerous factors can influence the potential indoor air concentration arising from vapor intrusion. EPA, therefore, generally recommends collecting, evaluating, and weighing multiple lines of evidence to characterize the vapor intrusion pathway. Some of these significant factors are illustrated in Figure 2-2.

The document *Conceptual Model Scenarios for the Vapor Intrusion Pathway* (EPA 2012b) provides simplified simulation examples to illustrate graphically how several of the subsurface and building-specific factors work together to determine the distribution of volatile contaminants in the subsurface and the indoor air concentration relative to a source concentration. The conceptual model scenarios document offers insights into the factors influencing the vapor intrusion pathway. It provides a theoretical framework with which to draw inferences about and better understand the complex vapor fate and transport conditions typically encountered at actual, non-idealized contaminated sites. The following general observations can be made from these simplified simulation examples, and may be useful when considering the vapor intrusion pathway at a particular site:

- The horizontal and vertical distance over which vapors may migrate in the subsurface depends on the source concentration, source depth, soil matrix properties (e.g., porosity and moisture content), and time since the release occurred. Months or years may be required to fully develop vapor distributions in the vadose zone at sites with deep vapor sources or with impedances to vapor migration arising from hydrologic or geologic conditions.

- Vapor concentrations in the subsurface may not be uniform in sub-slab soil gas or in soil gas at similar depths exterior to the building of interest. Therefore, vapor concentration at exterior locations (i.e., outside a building's footprint) may be substantially different from the concentration underneath the building (e.g., the sub-slab concentration), depending on site-specific conditions and the location and depth of the exterior soil gas sample.

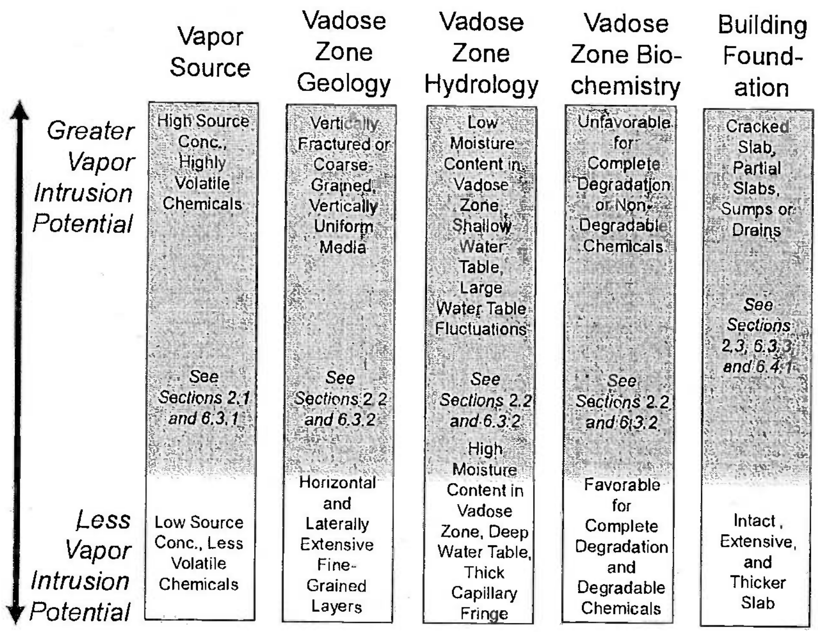

Figure 2-2 Some Factors that Affect Vapor Intrusion

- Simulations assuming an idealized, constructed ground cover suggest that shallow soil gas concentrations can be greater under low-permeability ground covers than under soil open to the atmosphere.

- The soil gas distribution beneath a building is not the only factor that determines the indoor air concentration. The indoor air concentration is also influenced by building conditions, including the presence of openings (e.g., cracks, utility penetrations) in the foundation, building pressurization, and the air exchange rate.

- Advective flow into buildings occurs predominantly near cracks and openings in the foundation slab and may affect the distribution of vapor-forming chemicals directly beneath the structure. Heterogeneities in the permeability of geologic materials and backfill, along with wind effects and building and atmospheric pressure temporal variation, may also contribute to the spatial and temporal variability of vapor concentrations in sub-slab soil gas and indoor air.

- Subsurface heterogeneities in site geology, such as layering and moisture content, influence the extent and rate of vapor migration from a contaminant source to overlying or adjacent buildings.

- The soil gas distribution of aerobically biodegradable chemicals (e.g., BTEX) can be significantly different than that of other chemicals that are not biodegradable (i.e., are recalcitrant) in similar settings. Specifically, the vapor concentrations of aerobically biodegradable chemicals exhibit greater attenuation than those of recalcitrant chemicals when the subsurface availability of oxygen is adequate.

Given the foregoing conceptual model of vapor intrusion and summary of modeled scenarios (EPA 2012b), the degree to which vapor intrusion is a pathway of concern can vary widely from site to site and from building to building within a site. Field observations and measurements demonstrate this—that is, indoor air concentrations and soil gas concentrations can exhibit significant temporal variations even for a single building (EPA 2012a) and suggest that the mass flux of vapors via soil gas entry may be highly variable, perhaps even episodic rather than continuous, due to varying driving forces and sub-slab soil gas concentrations.

2.5 Consideration of Indoor and Outdoor Sources of VOCs

Indoor air in many buildings will contain detectable levels of a number of vapor-forming chemicals whether or not the building overlies a subsurface source of vapors (EPA 2011a), because indoor air can be impacted by a variety of indoor and outdoor sources. Indoor sources of volatile contaminants include the use and storage of consumer products (e.g., cleaners, air fresheners, aerosols, mothballs, scented candles, and insect repellants), combustion processes (e.g., smoking, cooking, and home heating), occupant activities (e.g., craft hobbies, home improvements, automotive repairs), and releases from interior building materials (e.g., carpets, insulation, paint, and wood-finishing products). Outdoor sources of volatile chemicals may arise due to releases from nearby sources such as industrial facilities, vehicles, yard maintenance equipment, fuel storage tanks, and paint or pesticide applications; regional sources such as air emissions from regional industry, vehicle exhaust, agricultural activities, and fires; or global sources, such as distant air emissions. The outdoor air surrounding a building is referred to as "ambient air" throughout the Final VI Guidance. The contribution of indoor and outdoor sources of vapors (or both) to indoor air concentrations is referred to as "background" throughout this guidance.

To determine if subsurface sources are responsible for indoor air contamination, EPA recommends that such background sources of air contaminants be identified and distinguished from volatile contaminants arising from vapor intrusion. Section 6.3.5 of the Final VI Guidance describes and recommends approaches for this purpose.

3.0 OVERVIEW OF VAPOR INTRUSION GUIDE

This section provides an overview of this guidance document and the general framework of the vapor intrusion assessment and mitigation process, which is illustrated in Figure 3-1. This section opens with a description of subsurface contaminants that have the greatest potential to pose a health concern via vapor intrusion, based upon their volatility and toxicity.

3.1 Contaminants of Potential Concern

Several physicochemical criteria may be considered for defining volatility[26] and identifying when toxic chemicals are present at levels of potential health concern. For purposes of this guidance, a chemical generally is considered to be "vapor-forming" if:

1) its molecular weight is less than 200 grams per mole (g/mol) (EPA 1991b, Section 3.1.1), vapor pressure is greater than 1 milliliter of mercury (mm Hg), or Henry's law constant (ratio of a chemical's vapor pressure in air to its solubility in water) is greater than 10^{-5} atmosphere-meter cubed per mole (atm m^3 mol^{-1}) (EPA 1991b, Section 3.1.1; EPA 2002c, Appendix D); and

2) the vapor concentration of the pure component exceeds the indoor air target risk level if the vapor source is in soil, or, if in groundwater, the saturated vapor concentration exceeds the target indoor air risk level.

Appendix A identifies chemicals that meet these criteria. EPA recommends that these chemicals be routinely evaluated during vapor intrusion assessments conducted in accordance with the Final VI Guidance, when they are present as subsurface contaminants.[27]

3.2 Vapor Intrusion Assessment

The approach for assessing vapor intrusion will vary from site to site, because each site will differ in its circumstances. For example, the information available for evaluating vapor intrusion potential will vary depending upon when vapor intrusion is first considered during a site's investigation-and-cleanup life cycle. Many sites can be evaluated for potential vapor intrusion during the normal course of an initial site assessment. Examples include brownfield sites that are intended for redevelopment and buildings where chemical odors have been reported. The data available for evaluating vapor intrusion may be very limited at the outset for these situations. At the other end of the investigation and cleanup life cycle, certain sites with long-

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[26] In chemistry and physics, volatility refers to the tendency of a substance to form vapors, which are molecules in a gaseous state, and escape from a liquid or solid. Volatility is directly related to a substance's vapor pressure and Henry's law constant. Volatility is indirectly related to a substance's molecular weight (i.e., substances with lower molecular weights tend to volatilize more readily than substances with similar molecular structures that have higher molecular weights).

[27] The list of vapor-forming substances warranting consideration for potential vapor intrusion may be modified in the future as toxicity values are updated.

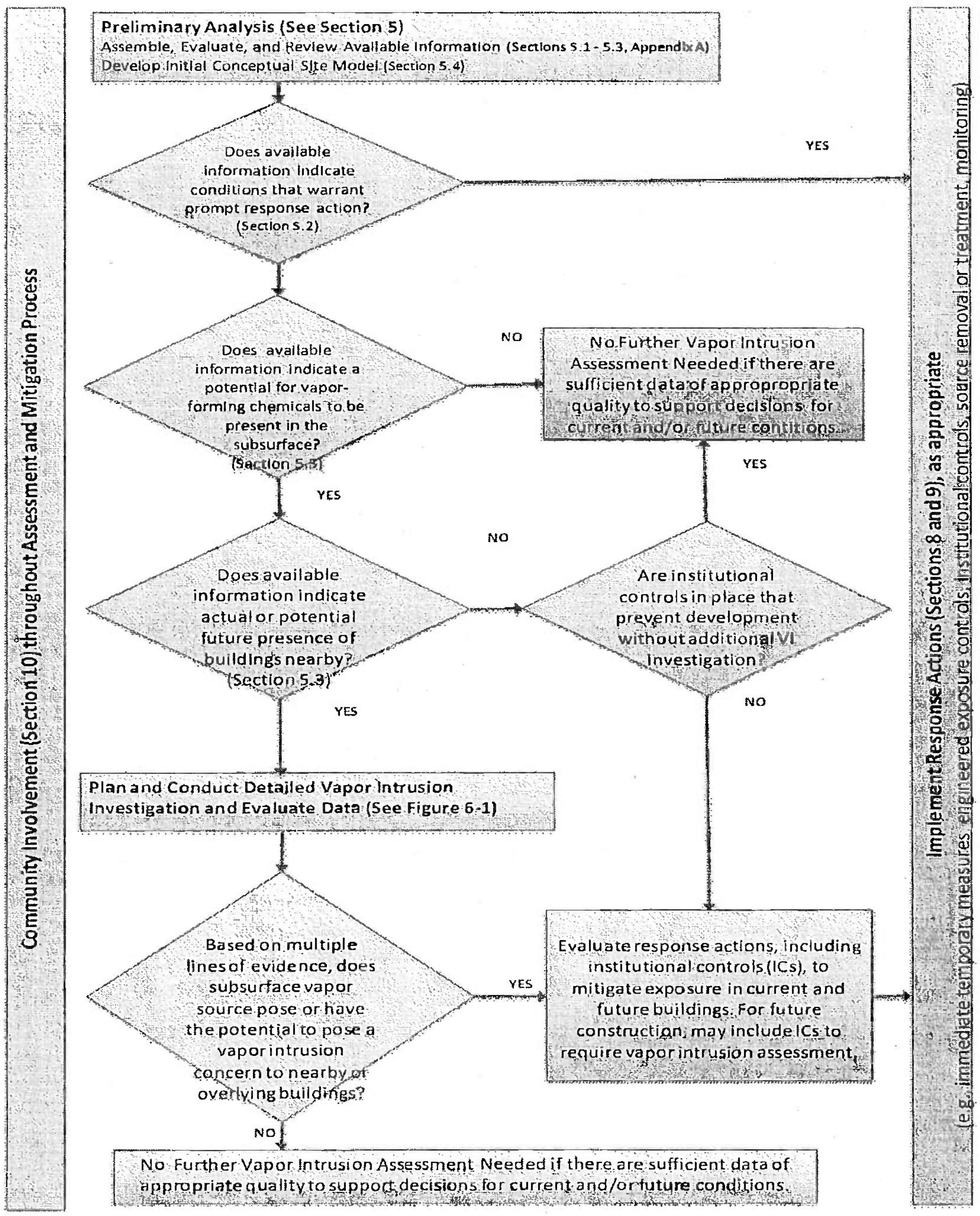

Figure 3-1 Overview of Vapor Intrusion Assessment and Mitigation

term cleanups underway for contaminated groundwater may be evaluated for vapor intrusion during periodic reviews of remedy performance and groundwater monitoring data.[28] In such situations, detailed information about the nature and extent of subsurface contamination and the relevant hydrogeologic conditions may already exist. In addition, there are different scenarios for vapor intrusion (EPA 2012b), depending on characteristics of the source (e.g., types, chemicals of concern, mass, distribution, and distance from building(s)), subsurface conditions and migration pathways (e.g., soil types and layering, existence of preferential pathways due to geology or infrastructure, and existence of any impediments to vapor migration), building susceptibility (e.g., age, design, construction, condition), lifestyle factors (e.g., keeping windows open or closed), and regional climate. For these reasons, every site (and every building) will not warrant the same approach to or intensity of assessment for vapor intrusion.

Broadly speaking, two general levels of vapor intrusion assessments can be distinguished:

1) A <u>preliminary analysis</u> utilizes available and readily ascertainable information to develop an *initial* understanding of the potential indoor air exposure and risk posed by vapor intrusion, which would typically be performed as part of an initial site assessment. The recommended information, approaches, and practices for conducting a preliminary analysis are described in Section 5.0.

2) A <u>detailed investigation</u> is generally recommended when the preliminary analysis indicates that subsurface contamination with vapor-forming chemicals may be present underlying or near buildings. It is typically performed as part of the site investigation stage. The recommended approaches and practices for conducting detailed vapor intrusion investigations are described in Section 6.0.

Considerable information, primarily empirical, has been generated regarding evaluation of the vapor intrusion pathway since the pathway emerged as a national issue in the late 1990s and especially in the past ten years. Broadly speaking, this information demonstrates that the vapor intrusion pathway can be complex. (The conceptual model of vapor intrusion provided in Section 2.0 identifies many of the potential complicating factors.) As a result, current practice suggests that the vapor intrusion pathway generally be assessed using multiple lines of evidence.

Therefore, EPA recommends that site assessors generally collect and evaluate multiple lines of evidence, including qualitative information, to support decision-making regarding the vapor intrusion pathway. Lines of evidence to evaluate the vapor intrusion pathway were identified in Section 2.0 and are discussed further in Sections 5.0 through 7.0.

3.3 Building Mitigation and Subsurface Remediation

The NCP expresses the preference for response actions that eliminate or substantially reduce the level of contamination in the source medium to acceptable levels, thereby achieving a permanent remedy. In the case of vapor intrusion, such a response action would entail

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[28] These situations can arise, for example, if the groundwater remedy was selected in the 1980s (long before vapor intrusion became recognized as a potentially significant exposure pathway), or if supplemental groundwater data indicate that the plume is migrating toward new inhabited areas.

eliminating or substantially reducing the level of vapor-forming chemicals in groundwater and subsurface soil via remediation. Section 8 discusses source remediation and associated institutional controls (ICs) and monitoring for vapor intrusion mitigation, including criteria for their termination.

Because comprehensive remediation[29] of the subsurface environment often entails prolonged periods to attain cleanup levels, problems of unacceptable vapor intrusion are often promptly addressed, at least on an interim (early action) basis, by engineered exposure controls for mitigating vapor intrusion into buildings. Engineered exposure controls[30] can generally be deployed and generally become effective quickly. Interim building mitigation methods are authorized by the NCP (Section 9.0), as necessary and appropriate, to promptly reduce threats to human health. Section 8 also summarizes technical information about specific exposure controls and provides guidance about their operation, maintenance and monitoring and associated ICs, including criteria for their termination.

Functionally, engineered exposure controls can be categorized into two basic strategies:

- Those that seek to prevent or reduce vapor entry into a building. These methods are more commonly implemented when needed. [31]
- Those that seek to reduce or eliminate vapors that have entered into a building,

In accordance with the foregoing conceptual model of vapor intrusion (Section 2.0), entry of the vapors into a building may be prevented or reduced by any of several techniques, which have the following objectives:

- Remove or reverse the driving forces (e.g., mitigate building under-pressurization) for vapor intrusion into the building.
- Eliminate or minimize identified vapor entry routes into the building (e.g., caulking, grouting, or otherwise sealing all holes, cracks, sumps and other foundational openings or creating a barrier between the soil and the building that blocks entry routes from the soil gas into the building).

Engineered exposure controls that entail mechanical systems and forces are often referred to as "active." Engineered exposure controls that do not involve mechanical operations are often

[29] For purposes of this document, "remediation" is intended to apply to interim and final cleanups, whether conducted pursuant to RCRA corrective action, the CERCLA removal or remedial programs, or using EPA brownfield grant funds with oversight by state and tribal response programs. In addition to permanent remedies for subsurface vapor sources, site remediation may also entail implementation of ICs and construction and operation of engineered systems to reduce risks to human health and the environment posed by environmental pathways other than vapor intrusion.

[30] Even when operated for prolonged periods, mitigation systems can be considered 'interim' remedies for purposes of this guidance, because their implementation does not substitute for remediation of the subsurface source(s) of vapor-forming contamination.

[31] Mitigation methods that prevent or reduce vapor entry into a building from subsurface sources would generally also be expected to reduce radon entry.

referred to as "passive." Many building mitigation systems rely on both active and passive strategies.

Engineered exposure controls that seek to reduce or eliminate vapors that have entered into a building can also be effective. In some instances, they can be implemented more readily than engineered exposure controls that reduce or eliminate entry of the vapors into a building. Typically, the simplest approach to limiting the concentration levels in occupied indoor spaces is to increase building ventilation (i.e., increase the rate at which indoor air is replaced with outdoor air).[32] Alternatively, vapor-forming chemicals are removed from indoor air using an adsorbing material (such as activated carbon) that can be either properly disposed of or recycled. Building mitigation methods that act upon vapor-forming chemicals in indoor air (i.e., rely upon enhanced ventilation or treatment) are generally capable of reducing background levels of chemicals, in addition to reducing indoor levels of vapor-forming chemicals that intrude from subsurface sources.

3.4 Preemptive Mitigation ("Early Action")

There may be situations where a party may wish to implement mitigation or control measures for vapor intrusion, even though only limited lines of evidence or measurements may be available to characterize the overall vapor intrusion pathway. For example, a party may be aware that vapor intrusion has been documented at neighboring structures, where measures are being implemented to mitigate the vapor intrusion pathway. A party may conclude there is a reasonable basis to take action, but each building presents a fact-specific situation that calls for its own individual judgement. Likewise, it may be appropriate and cost-effective to design, install, operate, and monitor engineered exposure controls for individual buildings to mitigate vapor intrusion in newly constructed buildings, or in buildings to be constructed in the future, that are located in areas of vapor-forming subsurface contamination, rather than potentially allow vapor intrusion to occur later and assess vapor intrusion after the fact.

The term "preemptive mitigation/early action" is used in this guidance to describe these situations.[33] The decision for preemptive mitigation/early action arises from precaution and from recognizing that:

- Installing engineered exposure controls in buildings is typically a cost-effective means of protecting human health and normally can be implemented relatively quickly in many buildings while subsurface contamination is being delineated or remediated.

[32] Exhausting air from the building will generally contribute to building under-pressurization, which may result in increased intrusion of soil gas into the building, which may offset the advantages of ventilation. On the other hand, introducing outdoor air at a rate slightly greater than the exhaust rate can create over-pressurization, which opposes the primary driving force for vapor intrusion. In these ways, ventilation may also affect the driving forces for vapor intrusion. In addition, it can be difficult to establish a ventilation rate that mitigates vapor intrusion and yields an environment conducive to human occupancy (e.g., considering air temperature or moisture).

[33] The term 'preemptive' has been used to describe the use of various types of controls that can prevent vapor intrusion from occurring prior to having fully demonstrated that unacceptable vapor intrusion currently exists in specific buildings being considered (EPA 2010).

- Conventional vapor intrusion investigations can be disruptive for building occupants (residents, workers, etc.) and owners.

- Comprehensive subsurface characterization and investigation of vapor intrusion can entail prolonged study periods, during which time building occupants and owners and others may have questions and concerns about potential risks from indoor air exposures to subsurface vapors.

Early action and interim action are allowed by federal environmental protection statutes, regulations, and guidance, including CERCLA, as amended, and RCRA, as amended – see Section 9.2 of the Final VI Guidance. Other aspects of preemptive mitigation/early action are also discussed in Section 9.0, including situations and criteria for decision-makers to consider.

3.5 Community Outreach and Involvement

OSWER is committed to enhancing transparency and improving upfront collaboration with community stakeholders regarding land cleanup, emergency preparedness and response, and management of hazardous chemicals and wastes. OSWER's Community Engagement Initiative (CEI), in particular, is designed to enhance OSWER's and the Regional offices' engagement with local communities and stakeholders (e.g., state and local governments, tribes, academia, private industry, other federal agencies, and nonprofit organizations) to help them participate meaningfully in government decisions regarding OSWER's nationwide programs.

Proper and sustained community outreach and engagement efforts are critical to the effective implementation of work plans for site-specific vapor intrusion assessment and mitigation. Because assessing the vapor intrusion pathway may involve sampling in a home or workplace, as well as other temporary inconveniences (e.g., assisting in reducing indoor sources of contaminants), individual, one-on-one communication with each property owner or renter generally should be considered. Building-by-building contact and communication are recommended as the most effective means of educating the community and obtaining access needed to assess, mitigate, and monitor the vapor intrusion pathway. Personal contact is further recommended to establish a good working relationship with each home or building owner or renter and to build trust. In many instances, local churches, ethnic organizations, and other community groups can be sought for assistance in reaching out to affected community members.

Vapor intrusion education and training are important components of proper and sustained community outreach and engagement efforts. Informing affected citizens about the vapor intrusion pathway and the cleanup process can contribute to building trust and can lay a better foundation for fostering meaningful community participation in the overall assessment and risk management process.

Recognizing the importance of proper community outreach and engagement efforts, EPA staff are highly encouraged to consult with colleagues experienced in community outreach and utilize available EPA planning resources, including those discussed in Section 10.0, which provides OSWER's community involvement planning guide for vapor intrusion projects. Like EPA, the ITRC also recommends implementing a community outreach program that provides timely information to concerned citizens and property owners.

4.0 CONSIDERATIONS FOR NONRESIDENTIAL BUILDINGS

This section summarizes EPA's general recommendations to consider in making decisions about evaluating and addressing potential vapor intrusion for nonresidential buildings pursuant to CERCLA and RCRA, including decisions that a response action or corrective action is not currently warranted. As used in this guidance, the phrase "nonresidential buildings" may include, but is not limited to, institutional buildings (e.g., schools, libraries, and hospitals), commercial buildings (e.g., hotels, office buildings, and retail establishments); and industrial buildings where vapor-forming substances may or may not be routinely used or stored.

When evaluating nonresidential buildings at sites that have subsurface contamination with vapor-forming chemicals, EPA generally recommends that building owners or lessees be contacted for information about building occupants potentially exposed to subsurface vapor intrusion, as well as any training, equipment, or engineering controls to mitigate inhalation exposures. Building occupants include workers, as well as expected visitors, customers, and suppliers. EPA generally should take all appropriate actions to protect human health and the environment from subsurface sources of chemical exposure in accordance with federal statutes,[34,35] regulations, and OSWER guidance,[36] taking into account the workplace setting. These actions may include sampling indoor air to assess exposure levels of building occupants to subsurface contaminants and implementing interim mitigation measures to control, reduce, or eliminate exposure indoors to vapors emanating from subsurface sources.

The approach for investigating vapor intrusion will vary from site to site, and from building to building, due to site- and building-specific factors and circumstances, including the nature, locations, and extent of subsurface contamination and the size, structural conditions and uses of buildings, and background levels in the workplace. Generally, EPA should consider the following factors when making decisions pertaining to vapor intrusion at nonresidential buildings, including decisions as to whether indoor air sampling, soil gas sampling underneath the building, or interim measures to mitigate vapor intrusion and reduce associated indoor air exposures for a nonresidential building may be warranted:

1) The characteristics of the populations potentially exposed to vapor-forming chemicals in the indoor air of the nonresidential building, including, for example, whether:

    a) Members of the general public are or may be present under current conditions.

    b) Sensitive populations (e.g., children) are or may be present under current conditions.

    c) Minority, low-income, or indigenous populations are or may be present under current conditions who may experience disproportionate impacts.

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[34] Protection of human health and the environment is required by CERCLA and RCRA and is addressed in the NCP, as summarized in Section 1.2.

[35] See, for example, CERCLA Section 101(22).

[36] See, for example, OSWER Directive 9355.0-30 (*Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*) (EPA 1991a).

2) The potential for vapor intrusion and any existing or planned engineering or institutional controls in the building. Questions to consider include, for example:

    a) Can subsurface vapor intrusion be identified as a potential cause of unacceptable human health risk to building occupants?

    b) Can subsurface remediation (e.g., excavation of contaminated soil or soil vapor extraction beneath the subject building) that is planned or underway reduce risk to human health from vapor intrusion within a time frame that is protective for any potential current or near-term exposures in the building?

    c) Are airborne toxic chemicals independent of any vapor intrusion (e.g., indoor use and storage of chemicals) present in the nonresidential building? Are the chemicals the same as the vapor-forming toxic substances in the subsurface? How does the risk from indoor exposure to these indoor-sourced chemicals and concentrations compare to known or potential risk arising from vapor intrusion?

    d) Do work practices and engineering controls currently in place ensure protection of all building occupants who may be exposed via the vapor intrusion pathway?

    e) Are enforceable ICs or other control mechanisms in place to ensure that current land use and workplace practices remain protective regarding indoor air exposures from vapor intrusion to all building occupants? Have these ICs and control mechanisms been communicated and documented to EPA? Can they be readily monitored and enforced?

EPA recommends documenting any decision not to undertake investigation or mitigation for vapor intrusion in a nonresidential building. EPA may consider reviewing these decisions, as appropriate, if the land use changes or new information becomes available that suggests circumstances supporting past risk management decisions have changed and prompt the need to revisit those decisions.[37] It is recommended that EPA request from property owners and building tenants timely notification of significant changes in building ownership, uses, access by the general public, or building construction (e.g., renovations), which may affect its risk management decisions pertaining to potential vapor intrusion assessment and mitigation, subsurface remediation, or ICs.

Regardless of decisions about indoor air sampling, soil gas sampling underneath the building, or interim measures to mitigate vapor intrusion, EPA may proceed with activities such as the following:

- Subsurface investigation to delineate the areal extent of a subsurface vapor plume in accordance with applicable statutes, regulations and OSWER guidance.

[37] OSWER Directive 9200.2-84 (EPA 2012d) provides a recommended framework for considering vapor intrusion while evaluating remedy protectiveness in the context of the Superfund five-year review process.

- Subsurface remediation to reduce or eliminate subsurface sources of vapors in accordance with applicable statutes, regulations and OSWER guidance in order to protect human health and the environment.

5.0 PRELIMINARY ANALYSIS OF VAPOR INTRUSION

A site may be identified based on reports to the National Response Center, citizen complaints or inquiries, state agency referrals, or other information (e.g., site history, land use, site inspections) obtained by EPA. This section describes EPA's recommended approach for conducting preliminary analyses for vapor intrusion using pre-existing and readily ascertainable information to develop an initial understanding of the vapor intrusion potential at a site.

Depending upon the nature and reliability of the available information, it may be possible to determine whether a vapor intrusion investigation or a response action is warranted. If the available information is not reliable or adequate for these purposes, however, additional data collection generally is recommended.

This section:

- Explains the recommended types of information that generally should be obtained when a site is first considered for vapor intrusion (see Sections 5.1, 5.3, 5.4, and 5.5).
- Identifies some of the site conditions for which prompt action is generally warranted (see Section 5.2).
- Illustrates some of the site conditions for which further evaluation of the vapor intrusion pathway might be warranted (see Sections 5.3, 5.4, and 5.5).
- Describes the recommended approaches to evaluating the reliability of pre-existing information, including any sampling data (see Sections 5.1 and 5.5).

5.1 Assemble, Evaluate, and Review Available Information

The recommended first step in a preliminary analysis generally entails assembling and reviewing relevant information that is available at the time for the site. At a minimum, information about potential subsurface sources of vapors and the presence of nearby buildings should be developed and evaluated. For some sites, such as sites being evaluated for redevelopment (EPA 2008a), information about contiguous or nearby facilities also may be relevant, because vapors can encroach from nearby facilities due to migration of contaminated groundwater or soil gas, even though vapor-forming chemicals may not have been used at the site.

The following recommended types of information are often available through documents (e.g., federal, state, tribal and local government records) or through interviews with individuals knowledgeable about the facility or site (e.g., past and present owners, operators and occupants; area residents or workers):

- History and descriptions of the types of operations and activities that occurred on or near the site.
- Information or records about the types of chemicals that may have been used or disposed of at the site.

- Information such as the occurrence of odors, reports of dumping liquids at the site, observations of unreported waste disposal practices, or other indications of chemical presence and release.

- Adverse physiological effects reported by building occupants (e.g., dizziness, nausea, vomiting, confusion).

- Evidence of subsurface intrusion of groundwater (e.g., wet basements) reported by building owners or occupants.

Such information usually can be reviewed and weighed together to assess whether vapor-forming chemicals (see Section 3.1) were used, stored, or handled at or near the site and were or may have been released to the subsurface environment. In general, anecdotal information obtained in interviews should be used cautiously.

In addition, the following types of information may be available through documents, interviews with individuals knowledgeable about the facility or site, or reconnaissance and site inspection:

- Locations, ownership, occupancy, and intended use of buildings on or near the site.

- Current and reasonably anticipated future land use on and near the site.

- Location of subsurface utility corridors.

Evaluation of such information usually can help determine whether human populations are present currently or are reasonably expected to be present in the future, who may become exposed to any intrusion of vapors from the subsurface into a building(s). Zoning, land use planning, and related information may also need to be consulted to identify reasonably anticipated future land use and building types in areas where buildings do not exist or to ascertain whether reasonably anticipated uses of existing buildings are likely to change.

The available data should be evaluated to identify any data gaps for purposes of the preliminary analysis. For example, has the history of operations and primary activities been established for the site and all contiguous properties, including currently vacant land? To the extent that there are significant data gaps, EPA recommends that additional data gathering (e.g., interviews, records review) generally be planned and conducted.

The available data also should be evaluated to assess its reliability and internal consistency. For example, if the available information about operations and activities at a specific property comes only from area residents, EPA recommends additional efforts to identify, contact, and interview current and past owners to obtain this information. For example, if anecdotal information about current activities at a specific property is in conflict with common knowledge about local zoning, EPA recommends that additional data gathering and evaluation be identified, planned, and conducted to resolve the inconsistency.

Section 5.5.1 describes additional considerations for evaluating the reliability of sampling data that may be available for some sites at the preliminary analysis stage.

5.2 Identify and Respond to Any Condition that Warrants Prompt Action

The following conditions generally indicate a need for prompt action:

- Explosive conditions posing safety concerns that warrant urgent intervention are reasonably suspected to exist when measured concentrations of vapors in the building, utility conduits, sumps, or other subsurface drains directly connected to the building exceed one-tenth (10%) of the lower explosive limit (LEL).[38] EPA recommends evacuation of buildings with potential explosion and fire hazards, along with notification of the local fire department about the threat.

- Conditions posing health concerns that warrant urgent intervention are reasonably suspected to exist when estimated exposure concentrations of vapors in the building exceed health-protective concentrations for short-term or acute exposure, as described in Section 7.5.2. Ventilation, indoor air treatment, or evacuation may be implemented to mitigate these conditions promptly (see Section 8.2.1).

The following conditions may indicate a need for prompt action:

- Odors reported by occupants, particularly if described as "chemical," "solvent," or "gasoline." The presence of odors does not necessarily correspond to adverse health or safety impacts, and the odors could be the exclusive result of indoor vapor sources; however, it is generally prudent to investigate any reports of odors as the odor threshold for some chemicals exceeds their respective LEL or health-protective concentrations for short-term or acute exposure.

- Physiological effects reported by occupants (e.g., dizziness, nausea, vomiting, confusion, etc.). These effects may or may not be due to subsurface vapor intrusion (or even other sources of indoor vapors); however, it is generally prudent to investigate any such reports.

- Wet basements in areas where groundwater is known to contain vapor-forming chemicals (Appendix A) and the water table is shallow enough that the basements are prone to groundwater intrusion or flooding. This condition is particularly important where there is evidence of light NAPL (LNAPL) on the water table directly below the building or direct evidence of intrusion of liquid-phase contamination (i.e., liquid chemical or dissolved in water) inside the building.

EPA generally recommends testing of indoor air (see Sections 6.4.1 and 6.3.4) as soon as practical in buildings where chemical odors, physiologic effects, or intruding contaminated groundwater are reported. When the results of such testing reveal hazardous conditions

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[38] The Occupational Safety and Health Administration of the U.S. Department of Labor (OSHA) considers concentrations in excess of one-tenth of the LEL to be a hazardous atmosphere in confined spaces [29 CFR 1910.146(b)]. The National Institute for Occupational Safety and Health (NIOSH) has designated such concentrations as immediately dangerous to life or health (IDLH).The Vapor Intrusion Screening Level Calculator (EPA 2012c) provides LELs for vapor-forming chemicals to facilitate identification of potential explosion hazards, as discussed further in Section 7.5.1.

warranting prompt response action, then ventilation, indoor air treatment, or evacuation may be implemented to mitigate these conditions promptly (See Section 8.2.1).

Preemptive mitigation/early action (see Section 9.0) may still warrant consideration after urgent safety or urgent health concerns have been addressed. Expected work conditions and anticipated hazards should be described and addressed in health and safety planning for all building- or site-specific actions.

5.3 Determine Presence of Buildings and Vapor-forming Chemicals

Two conditions, at a minimum, must be present for the vapor intrusion pathway to pose a potential human health threat:

1) There must be a source of vapor-forming chemicals in the subsurface environment (i.e., in groundwater or soil, or a primary vapor release such as from natural gas transmission lines). Appendix A lists chemicals that typically have the potential to pose an unacceptable health risk through the vapor intrusion pathway. Those chemicals likely to be present as subsurface contaminants should generally be evaluated during vapor intrusion assessments conducted in accordance with this Final VI Guidance in areas where buildings are present or future buildings could be constructed above or near the subsurface vapor source(s). In the absence of environmental sampling data, the potential presence of vapor-forming chemicals in the subsurface may be inferred from site information, as identified in Section 5.1 (e.g., site history).

2) Buildings are present or could be constructed in the future above or "near" the subsurface vapor source(s). For purposes of this guidance and its recommendations for evaluating potential health risks posed by toxic vapors, "building" refers to a structure that is regularly occupied and used by humans (or could be occupied and used in the future). This would include, for instance, homes, offices, stores, commercial and industrial buildings, etc., but would not normally include open sheds, carports, pump houses, or other structures that are not regularly occupied by humans. For purposes of evaluating potential explosion hazards, however, the term "building" generally includes occupied and non-occupied structures. Existing buildings can be identified during inspections of the land areas overlying and near subsurface vapor sources. The potential presence of buildings in the future may be inferred from site information, as identified in Section 5.1. Buildings within 100 feet laterally of subsurface vapor sources (or 100 feet vertically of underlying vapor sources) should be considered "near" (see Section 6.2.1) for purposes of a preliminary analysis, under the assumption that preferential vapor migration pathways are absent.[39]

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[39] Preferential migration pathways are defined and discussed in Section 5.4. When present, they may facilitate subsurface vapor migration over distances greater than 100 feet.

If the available information is deemed reliable, well documented, and sufficient (see Section 5.1) and indicates that neither of these conditions is met, then it may not be appropriate to conduct further vapor intrusion assessments.[40]

> *Example: From 1920 to 1931, the ABC Mining Company obtained and shipped iron ore from a local deposit. Ore from the mine was shipped by rail to a different location where it was milled and processed to extract the metal. Although no company records are available for the mine, a review of mining techniques indicates that solvents and other vapor-forming chemicals were not used in the mining process during the 1920s and 1930s. Former mining structures have been removed, and the site is currently vacant. The city has proposed redeveloping the site with bike and hiking trails but no buildings or other structures for storage or site maintenance support. Based on the information and findings, the need for further assessment of the vapor intrusion pathway due to mining-related contamination is not indicated.*

If, on the other hand, there is evidence to demonstrate that a release of vapor-forming chemicals to the subsurface has occurred (e.g., environmental sampling data indicate detectable levels of a vapor-forming chemical(s) in potential source media)[41] or may have occurred underneath or near a property with buildings, then further vapor intrusion assessment is generally warranted, including development of a conceptual site model (see Section 5.4) and investigation of site-specific conditions (see Section 6.0).

> *Example: The XYZ Recycling Center site was used from 1963 to 1984 for the collection and recycling of industrial solvents and other fluids. The site was repeatedly cited by the State and City for improper handling and disposal of solvents, and was closed in 1985. Groundwater data indicate the presence of multiple CHCs. Buildings overlying the contaminated groundwater are currently used mainly for storage of non-chemical goods, but the site has been proposed for future residential or commercial redevelopment. Based on the foregoing information and findings, further assessment of the potential for vapor intrusion is warranted, including risk-based screening of the groundwater data (see Section 6.5).*

If a release of vapor-forming chemicals to the subsurface is known or suspected to have occurred at or near the site, but buildings are not present and none are reasonably anticipated in the future (e.g., the contaminated source underlies an open space, recreational area, or wildlife refuge), then further vapor intrusion assessments may not be appropriate. It may be appropriate, however, to establish an IC requiring a vapor intrusion investigation or building mitigation[42] in the future, in case land use were to change. ICs for building mitigation and

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[40] In accordance with federal environmental protection statutes, regulations, and OSWER guidance, a subsurface investigation may still be warranted for non-volatile substances and for other potential exposure pathways such as those identified in Section 1.3.

[41] Section 6.5 provides information on how such data may be used in a quantitative fashion to screen the site further.

[42] If, for example, a developer is considering acquiring and building on land that contains subsurface contamination with vapor-forming chemicals, the developer could retrofit existing buildings or build new buildings with vapor mitigation systems without first conducting an extensive vapor intrusion investigation (see Section 9.0). As summarized in Section 3.3, building mitigation systems for the vapor intrusion pathway may eliminate or minimize vapor entry routes and/or remove or reverse the driving forces for soil gas entry (i.e., may be passive and/or active).

subsurface vapor source remediation are discussed further in Section 8.6 of this guidance document. In addition, a subsurface investigation may be warranted at some point to characterize subsurface contamination and assess the need for subsurface remediation to protect the environment and human health for potential exposure pathways other than vapor intrusion. For example, site investigations to characterize the nature and extent of groundwater contamination and support assessments of risk to human health through the ingestion pathway are typically conducted in accordance with federal statutes and regulations (e.g., CERCLA and RCRA).

5.4 Develop Initial Conceptual Site Model

EPA recommends that the planning and data review team develop an initial conceptual site model (CSM) for vapor intrusion and conduct a site investigation for vapor intrusion (see Section 6) when the preliminary analysis indicates the presence of subsurface contamination with vapor-forming chemicals underlying or near buildings. The initial CSM (and any subsequent refined CSM) can be used to support evaluations of the adequacy of the available information, to guide any vapor intrusion investigations and to support data selection for risk-based screening (see Section 6.5). The CSM can also provide useful information for supporting prompt development of a strategy for early response actions (see Section 9.0). The remainder of this section discusses recommended information collection that can be useful for developing a CSM. Note that some of the recommended information may not be readily available when a site is first considered for vapor intrusion.

As noted in Section 2.0 and Section 5.3, for the vapor intrusion pathway to be complete, there must be, at a minimum, a source of vapor-forming chemicals in the subsurface and buildings or the potential for future buildings near the subsurface vapor source(s). Therefore, the CSM for vapor intrusion at a minimum should portray the current understanding of the site-specific conditions, including the following:

- Nature (i.e., type, chemical composition), location, and spatial extent of the source(s) of vapor-forming chemicals in the subsurface. For example, it is useful to know which vapor-forming chemical(s) primarily comprise the subsurface vapor source[43] and whether it is also capable of posing explosion hazards.

- Location, use, occupancy, and basic construction (e.g., foundation type) of existing buildings.

The CSM should also portray the current understanding of the hydrologic and geologic setting in and around the subsurface vapor source(s) and the buildings. When these conditions are not well established from existing information, and the preliminary analysis indicates the presence of subsurface contamination with vapor-forming chemicals underlying or near buildings, EPA

[43] EPA also recommends that the CSM identify any site-specific chemicals of concern that may be biodegradable. When evaluating biodegradable chemical contaminants, the CSM should identify and summarize information and data pertaining to the possible role of biodegradation *in situ* in limiting vapor migration in the vadose zone (see Section 6.3.2) or generating hazardous, volatile products (e.g., methane from anaerobic biodegradation, vinyl chloride as a byproduct of PCE or TCE biodegradation).

recommends that a detailed vapor intrusion investigation be scoped to address these data gaps (see Section 6.3).

Furthermore, the CSM should identify known or suspected preferential pathways that could facilitate vapor migration to greater distances and at higher concentrations than otherwise expected. EPA recommends that buildings with significant preferential pathways be evaluated closely. For the purposes of this guidance, a "significant" preferential pathway is a naturally occurring or anthropogenic (human made) subsurface conduit that is expected to exhibit little resistance to vapor flow in the vadose zone (i.e., exhibits a relatively high gas permeability) or groundwater flow (i.e., exhibits a relatively high hydraulic conductivity) and be of sufficient volume and proximity to a building so that it may be reasonably anticipated to influence vapor intrusion into the building. Significant vertical preferential pathways may result in higher than anticipated concentrations in the overlying near surface soils, whereas significant horizontal preferential pathways may result in elevated concentrations in areas on the periphery of subsurface contamination. Naturally occurring examples include fractures and macropores, which may serve as preferential pathways for either the vertical or horizontal migration of source materials and/or vapors. Anthropogenic examples include utility vaults and conduits, elevator shafts, subsurface drains, and permeable fill that intersect vapor sources or vapor migration pathways. In highly developed residential areas, extensive networks of subsurface utility conduits may be present, which can significantly influence the migration of contaminants.

CSMs for vapor intrusion assessments often need to consider two distinct exposure situations:

1) At some sites and contaminated locations, there are concerns as to whether vapor intrusion may pose a risk to current occupants of the buildings present. For this situation, EPA recommends that building-specific information be available to support the CSM.

2) At other sites and contaminated locations, buildings are not present, but are expected to be constructed, and building-specific information may not be available to support the CSM. For this situation, the CSM may need to consider a hypothetical building constructed anywhere over (or near) the subsurface source of vapor-forming chemicals.

In general, CSMs identify the potentially exposed populations, potential exposure routes, and potential adverse health effects (i.e., toxicity) arising from indoor air exposures. Therefore, the CSM also should identify and consider sensitive populations, including but not limited to:

- Elderly.
- Women of child-bearing age.
- Infants and children.
- People suffering from chronic illness.
- Disadvantaged populations (i.e., an environmental justice situation).

As noted in Section 2.0, the exposure route of general interest for vapor intrusion is inhalation of toxic vapors in indoor air and the human populations of primary interest are individuals living or working in or otherwise occupying a building subject to vapor intrusion. However, EPA recommends that the CSM also identify any site-specific chemicals of concern that have potential for explosion hazards (e.g., methane) or for posing other routes of exposure (e.g., dermal exposure to shallow contaminated groundwater seeping into a basement, which is contaminated).

In documenting current site conditions, EPA recommends that a CSM be supported by maps, cross sections, and site diagrams, and that the narrative description clearly distinguish what aspects are known or determined and what assumptions have been made in its development.

Developing a CSM generally should be the first step in EPA's data quality objective (DQO) process (EPA 2006a). It is rare for a site to have readily available sources of sufficient information to develop a complete CSM when the vapor intrusion potential is first considered. For example, a detailed site-specific investigation may be necessary to characterize the full extent of subsurface vapor sources and geologic conditions underlying nearby buildings (see Sections 6.3.1 and 6.3.2) and to demonstrate the absence of preferential pathways for vapor migration and intrusion. The CSM should be updated as new information is developed and new questions are framed and answered. A well-defined, detailed CSM may also facilitate the identification of additional data needs and development of appropriate detection limits for laboratory and field analyses, which can support planning of the detailed vapor intrusion investigation (see Section 6.2) and site-specific health risk assessment, if any (see Section 7.4). Sections 6.3, 6.4, 7.1, and 7.2 provide additional guidance about data collection and evaluation for purposes of supporting the CSM.

5.5 Evaluating Pre-Existing and Readily Ascertainable Sampling Data

Sites and adjacent facilities that have been the subject of previous environmental investigations or regulatory actions may already have data on contaminant concentrations in site media (i.e., sampling data) when vapor intrusion is first considered. Some of these sites and facilities may be undergoing remediation but warrant a vapor intrusion assessment as a result of changing toxicity information for vapor-forming chemicals, as part of a periodic review of remediation effectiveness and protectiveness, or for other reasons.

If the pre-existing environmental data are deemed reliable and other conditions are met (as described in the remainder of this subsection and in Section 6.5.1), the sampling data may be compared to recommended generic vapor intrusion screening criteria (see Section 6.5) for purposes of developing an initial quantitative perspective about the potential level of exposure and risk posed by vapor intrusion. Such a screening can, for example, help focus a subsequent vapor intrusion investigation (see Section 6.0) or provide support for considering building mitigation as an early action (see Section 9.0). Note that some of the site-specific information generally recommended for supporting a risk-based screening may not be available when a site is first considered for vapor intrusion.

5.5.1 Evaluate Sampling Data Reliability and Quality

To the extent that environmental sampling data are identified for the site or nearby properties, EPA recommends that these data be evaluated to determine whether they are of sufficient quality to support a comparison to recommended generic vapor intrusion screening criteria (see

Section 6.5). Some questions that could be considered when reviewing historical sampling data include:

- How were the samples collected and analyzed? EPA generally recommends using pre-existing data when they have been collected and analyzed by methods considered reliable by today's standards.

- How old are the data? Were analyses conducted for all known or suspected vapor-forming chemicals expected to be present and reasonably expected degradation products? EPA generally recommends using pre-existing data when they can be considered representative of current conditions.

- Were the reporting limits sufficiently low for comparison with vapor intrusion screening criteria? EPA generally recommends using pre-existing data with non-detect results when they can be considered reliable.

- Were multiple locations sampled to assess spatial variability of the results? Were multiple sampling events conducted to assess temporal variability of the results? EPA generally recommends characterizing spatial and temporal variability to increase confidence in data evaluation and decision-making.

EPA also recommends that the reliability of any historical sampling data be assessed by considering the principles for collecting subsurface and indoor air samples that are described in Sections 6.3.1 and 6.4 of the Final VI Guidance. In addition, the EPA's *Guidance for Data Usability in Risk Assessment, Part A* (EPA 1992a) outlines a recommended approach for evaluating whether the data meet the requirements and intended use of the risk assessment. As such, it is a good tool for evaluating the quality and usefulness of historical data collected at a site.

5.5.2 Evaluate Adequacy of the Initial CSM

Before performing any comparison of existing sampling data to recommended generic vapor intrusion screening criteria (see Section 6.5), it is important to verify that site-specific conditions reflect the conditions and assumptions of the generic model underlying the vapor intrusion screening criteria, which are summarized in Section 6.5.1. To verify that the generic vapor intrusion model applies, there is a need for basic knowledge of the subsurface source of vapors (e.g., location, form, and extent of site-specific vapor-forming chemicals) and subsurface conditions (e.g., soil type in the vadose zone, depth to groundwater for groundwater sources), which are important elements of the CSM (see Section 5.4). When these subsurface data are not available, EPA recommends they be collected (i.e., proceed to a detailed vapor intrusion investigation) before conducting risk-based screening of sampling data.

5.5.3 Preliminary Risk-based Screening

If reliable sampling data are available and an adequate CSM has been documented (i.e., sufficient subsurface characterization information exists to adequately characterize the locations, forms, and extent of site-specific vapor-forming chemicals and general subsurface conditions (e.g., hydrologic and geologic setting in and around the source(s) and the buildings)), then a risk-based screening may be useful to obtain some preliminary insights about the potential level of exposure and risk posed by vapor intrusion.

Example: A prospective developer of a vacant lot with no history of onsite chemical use is interested in evaluating the potential for vapor intrusion in the future due to potential migration onto the lot of an off-property plume of contaminated groundwater. The extent and nature of the off-property plume have been adequately and recently characterized and geologic conditions near the lot have been characterized, as documented in a publicly available report(s). In this circumstance, it may be possible to support a preliminary screening and obtain some useful insights. For example, if the maximum concentration of each chemical of concern in the off-property plume of contaminated groundwater currently and in the future is less than the generic chemical-specific screening level for groundwater, then vapor intrusion is not expected to be a future concern on the vacant lot, provided there are sufficient data to document that conditions on the vacant lot are in accordance with the generic model behind the vapor intrusion screening levels, as described in Section 6.5.1.

Additional data collection, possibly including on-property site characterization, may be warranted to verify that these conditions hold true (i.e., proceed to a detailed vapor intrusion investigation before making final risk management decisions). EPA generally also recommends using post-construction indoor air testing to confirm the screening results based upon the groundwater source data.

This example reinforces the following general recommendations:

- Site-specific data generally should be collected and evaluated to verify that the subject property reflects the conditions and assumptions of the generic model underlying the VISLs (see Section 6.5.1).
- Multiple lines of evidence (e.g., hydrogeologic information in addition to sampling data) generally should be collected and weighed together in supporting assessments of the vapor intrusion pathway (see Sections 7.1 and 7.2 for further information).
- Multiple rounds of groundwater (or soil gas) sampling results are useful in supporting conclusions that a specific vapor source is stable or shrinking and/or is not expected to pose a vapor intrusion concern (see Sections 6.3.1 and 6.4.5).

Similar recommendations apply in the situation where vapor intrusion potential is being evaluated as part of a periodic review of an existing remedy (prompted, for example, by recent construction of a new building over a contaminated plume that is undergoing remediation) (EPA 2002b, 2012d).

6.0 DETAILED INVESTIGATION OF VAPOR INTRUSION

This section describes EPA's generally recommended approaches and practices for vapor intrusion investigations, which typically entail collecting and evaluating multiple lines of evidence to characterize the vapor intrusion pathway. Section 7 describes EPA's generally recommended approaches and practices for determining, on the basis of the investigation results, whether the vapor intrusion pathway poses a potential health concern to building occupants under current and reasonably expected future conditions and whether response actions are warranted for vapor intrusion mitigation at individual facilities, buildings, or sites.

6.1 Common Vapor Intrusion Scenarios

Vapor intrusion scenarios can be quite varied, owing to the possible combinations of:

- Multiple hazardous chemicals that can form vapors.
- Multiple forms in which these chemicals may be present as contaminants in the subsurface, for example:
  - Residual NAPL and adsorbed-phase chemicals, including LNAPLs that are less dense than water and DNAPLs that are denser than water.
  - Dissolved-phase chemicals in groundwater or soil moisture.
  - Primary vapor releases (e.g., from gas transmission lines).
- The variety of geologic and hydrologic characteristics and conditions in the subsurface environment in which this contamination may occur.
- The variety of buildings (in terms of size, age, condition, and use) and current or expected land use settings (e.g., residential, commercial, industrial, brownfield redevelopment) that may be subject to vapor intrusion from such subsurface contamination.

A few of the possible scenarios are illustrated in Figure 2-1. Many more can be inferred from the conceptual model of vapor intrusion discussed in Section 2.0. Some of the more common scenarios where vapor intrusion has been documented to occur include:

- Groundwater contaminant plumes in shallow aquifers underlying residential and non-residential buildings.
- Soil contamination in the vadose zone underlying commercial or industrial buildings, even when the areal extent of groundwater contamination is limited.

EPA's recommended approaches and practices for vapor intrusion investigations aim to be flexible and adaptable to a wide range of reasonably expected scenarios and are not intended to be prescriptive or exhaustive for any specific scenario.

6.2 Planning and Scoping

Before information or data are collected on Agency-funded or regulated environmental programs and projects, systematic planning is conducted during which performance or acceptance criteria are developed for the collection, evaluation, or use of these data (EPA 2006a).[44] EPA strongly recommends the DQO process as the appropriate systematic planning process for its decision-making and has issued guidance for its application to hazardous waste site investigations pursuant to CERCLA and RCRA (EPA 2000). Appropriately conducted, planning provides greater assurance that the data collected will fulfill specific project needs and that mitigation and subsurface remediation options will be considered early in the process.[45] A clear and logical plan will often facilitate communication with building owners, occupants, and other stakeholders.

Given these considerations, thorough and sustained planning guided by a CSM is usually advisable for detailed vapor intrusion investigations. The initial stages of planning would typically entail gathering readily available existing information and formulating an initial CSM, as described in Section 5.4. The CSM portrays the current understanding of site-specific conditions, including the nature and extent of contamination, contaminant fate and transport routes, potential "receptors" and contaminant exposure pathways. The term "conceptual" merely reflects that the model need not be entirely quantitative and mathematical; it does not denote a simplistic or incomplete understanding of site conditions. The CSM should evolve and be updated as new information is developed and new questions are framed and answered.

Subsequent to formulating an initial CSM based on readily available information, the scope for an initial phase of vapor intrusion investigation would be developed, preferably along with a logical plan for future directions in response to the reasonably expected outcomes of the initial investigatory phases. Initial plans may warrant periodic updates and refinements, particularly when data outcomes are unexpected and prompt the need to reevaluate the CSM. In each case, EPA recommends that the investigation work plan include the identification of and basis for the indoor air screening levels (such as the VISLs) and/or indoor air action levels (i.e., level of each vapor-forming chemical of potential concern that would trigger a response action if exceeded), which would dictate the DQOs for the sampling and analysis methods. In general, the plan should also include a rationale or logic for where and how the data will be collected and over what duration(s), how the data will be interpreted, whether confirmatory sampling will be needed if all sample concentrations are less than the action levels, whether response action(s) would be triggered if sample concentrations exceed the target levels, and similar considerations. Sections 6.3 through 6.6 below provide additional guidance and information for planning and scoping site-specific investigations for vapor intrusion assessment. Figure 6-1 provides a diagram to illustrate such planning and scoping.

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[44] Appendix C provides additional information about EPA's quality system and DQO process.

[45] *Science and Decisions: Advancing Risk Assessment* was prepared by the National Academy of Sciences (NAS) Committee on Improving Risk Analysis Approaches Used by the U.S. EPA (NRC 2009) and is commonly referred to as the "Silver Book." Among other recommendations, the NAS Committee encouraged EPA to focus greater attention on design in the formative stages of risk assessment, specifically on planning and scoping and problem formulation, and to view risk assessments as a method for evaluating the relative merits of various options for managing risk, rather than as an end in itself. In accordance with these recommendations, plausible mitigation and subsurface remediation options (see Section 8) should be considered during development of vapor intrusion investigation plans.

EPA's fundamental approach to evaluating contaminated sites calls for proceeding in a stepwise fashion with early data collection efforts usually limited to developing a basic understanding of the site, as reflected in the CSM.[46] Subsequent data collection efforts focus on filling gaps in the understanding of the CSM and gathering information necessary to evaluate the relative merits of various options for managing risk. Therefore, it is generally recommended to develop and implement a vapor intrusion investigation plan in multiple stages or phases. Such a phased sampling approach encourages the identification of key data needs early in the process to better ensure that data collection provides information relevant to decision-making (e.g., interim action to mitigate vapor intrusion and selection of a cleanup plan for subsurface contamination). In this way, the overall site characterization effort can be scoped to prioritize data collection and minimize the collection of unnecessary data and maximize data quality.

Generally, EPA recommends that the objectives and methods of the investigation be documented in a vapor intrusion work plan. At a minimum, components of the work plan should generally include:

- Narrative description of the rationale and scope of the investigation.
- Summary of the CSM.
- Scaled map(s) illustrating extent of subsurface contamination and readily identifiable landmarks (e.g., streets and buildings).
- Media to be sampled.
- Number, type, and location of and rationale for proposed sampling locations.
- Sampling methods and procedures for each medium.
- Analytic method(s) to be used to obtain chemical concentrations.
- Standard operating procedures of the laboratory and for field instruments.
- Quality assurance project plan (QAPP).

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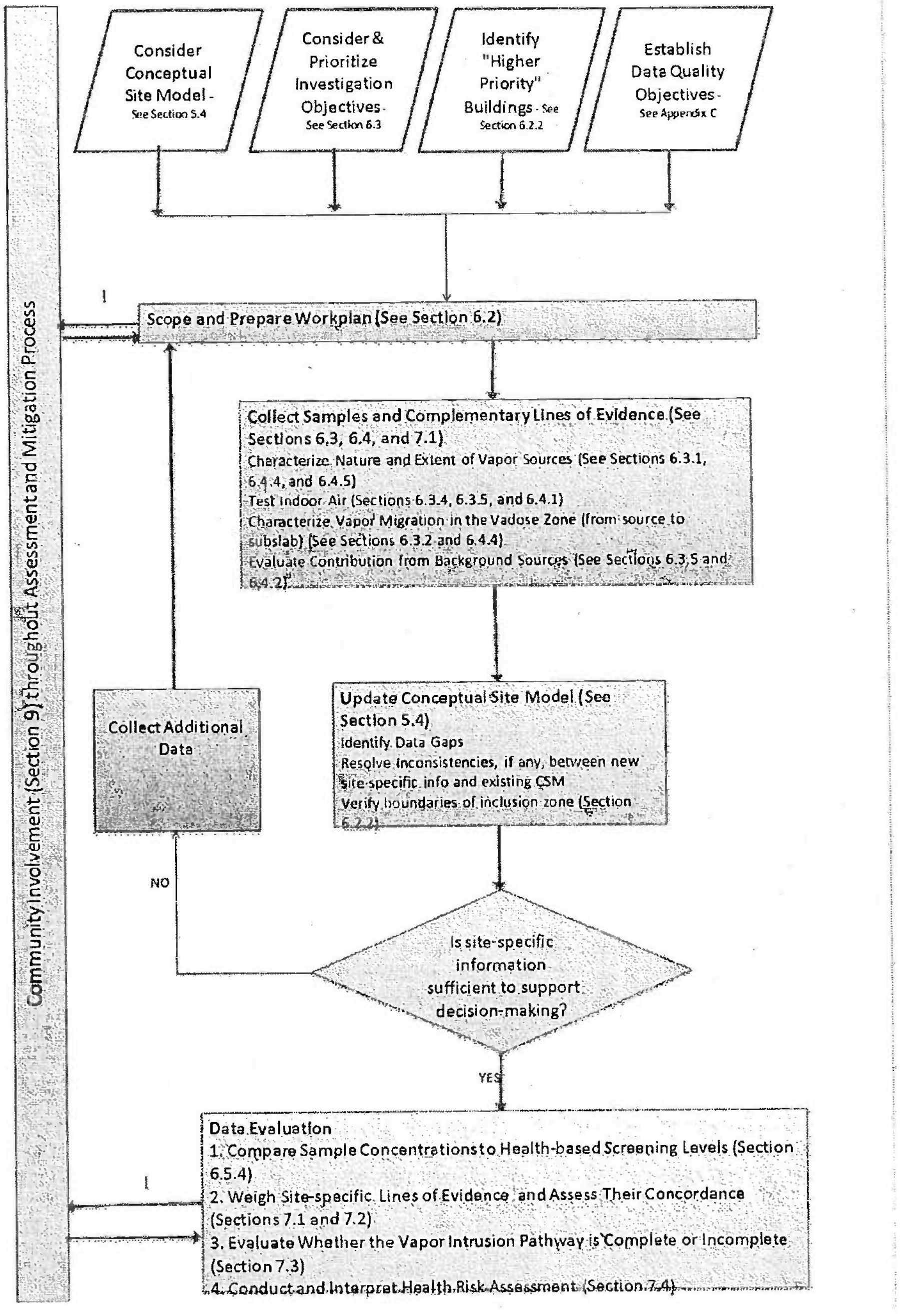
[46] Investigations under CERCLA and RCRA corrective action (CA) explicitly recognize phasing. In these cleanup programs, the first investigatory phase is an *initial site assessment*. The purpose of this activity is to gather information on site conditions (current and historical), releases, potential releases, and exposure pathways. Investigators use this information to determine whether a response action (e.g., removal action or interim cleanup measure) may be needed or to identify areas of concern for further study. Information collected during this phase usually forms the basis for determining whether the next stage, site investigation, is warranted. In the RCRA CA program, the initial site assessment is called the RCRA facility assessment. Under CERCLA, this phase is called the preliminary assessment/site inspection. The purpose of the second phase, site investigation, is to determine the nature and extent of contamination at a site, quantify risks posed to human health and the environment, and gather information to support the selection and implementation of appropriate remedies. In the RCRA CA program, this phase is known as the RCRA facility investigation. Under the CERCLA remedial program, this phase is referred to as the remedial investigation. In addition, the site investigation may itself be conducted in multiple stages (or phases).



Exclamation point (!) indicates important milestone for communication and engagement efforts with affected building occupants and owners.

Figure 6-1 Overview of Planning, Scoping, and Conducting Vapor Intrusion Investigations

- Health and safety plan.[47]

The planning and data review teams for vapor intrusion generally will need to include scientists or engineers with expertise in characterizing subsurface environmental conditions and interpreting and communicating environmental data. In addition, coordination with a human health risk assessor generally will be needed in evaluating the vapor intrusion pathway. Depending upon the complexity of the CSM (see Section 5.4) and data evaluations, these teams also may need to include scientists and engineers with expertise in hydrogeology, inferential statistics, laboratory analysis methods, and building construction, ventilation, and operations and individuals knowledgeable about land use planning, zoning, and land development. In addition, on-site personnel should have appropriate training and experience in hazard identification, workplace practices to foster health and safety, and recommended sampling protocols.

6.2.1 Vapor Intrusion Inclusion Zones

Vapor concentrations generally decrease with increasing distance from a subsurface vapor source, and eventually at some distance the concentrations become negligible. The distance at which soil gas concentrations become negligible is a function of the strength and dimensions of the vapor source, the type of vapor source, the soil types and layering in the vadose zone, the presence of physical barriers (e.g., asphalt covers or ice) at the ground surface, and the presence of preferential migration pathways, among other factors (see, for example, EPA 2012a). Because these factors vary among sites, the distance beyond which structures will not be threatened by vapor intrusion is necessarily a site-specific determination. The extent of the site-specific "inclusion zone" for vapor intrusion should also consider:

- The age of the chemical release and whether sufficient time has elapsed to allow soil gas to migrate from the source to its maximum potential extent.
- Whether the subsurface vapor source is stable or shrinking (i.e., is not migrating or rising in concentration, including hazardous byproducts of any biodegradation).

Recommended Distance for Initial Evaluation. There are limited published empirical data relating observed indoor air concentrations of subsurface contaminants to distance from a source boundary. However, a buffer zone of approximately 100 feet (laterally or vertically from the "boundary" of subsurface source concentrations of potential concern) has generally been used in determining which buildings to include in vapor intrusion investigations when significant surface covers are not present. Specifically, a buffer zone of 100 feet (or approximately two houses wide) has been suggested by several states (Folkes et al. 2007) and is supported, in general, by theoretical analyses that assume the absence of preferential vapor migration pathways and that diffusion is the predominant mechanism of vapor migration in the vadose

[47] All governmental agencies and private employers are directly responsible for the health and safety of their employees. This general rule applies to many parties involved in the assessment and cleanup of Superfund sites, RCRA corrective action sites, and brownfield redevelopment sites. Standards established pursuant to the Occupational Safety and Health Act are found in Title 29 of the Code of Federal Regulations (29 CFR), which include requirements for training, hazard communication, and site-specific health and safety plans.

zone (Lowell and Eklund 2004). On this basis, buildings within 100 feet laterally of subsurface vapor sources (or 100 feet vertically of underlying vapor sources) generally should be considered "near" for purposes of vapor intrusion investigations, under the assumption that preferential vapor migration pathways are absent.

Anecdotal evidence indicates that in some settings buildings greater than 100 feet from a plume "boundary" may be affected by vapor intrusion, even when diffusion is the presumed mechanism of vapor migration. Moreover, the presence of conduits (e.g., sewers or utility bedding) or preferential hydrogeologic pathways that facilitate unattenuated vapor migration in the vadose zone, and other factors (e.g., presence of extensive surface covers, uncertainties in delineating the boundaries) may extend the vapor migration distance. For these reasons, EPA recommends investigating soil vapor migration distance on a site-specific basis. That is, larger or smaller distances may need to be considered when developing objectives for detailed vapor intrusion investigations and interpreting the resulting data. Data from sub-slab and exterior soil gas sampling (see, for example, Sections 6.4.3, and 6.4.4) and indoor air testing (see, for example, Sections 6.3.4 and 6.4.1) can be collected and evaluated to delineate or confirm areas at specific sites within which buildings are subject to vapor intrusion threats.[48]

Finally, we would note that vapor source types for which use of a 100-foot buffer would typically be inappropriate include:

- Landfills where methane is generated in sufficient quantities to induce advective transport in the vadose zone.
- Commercial or industrial settings where vapor-forming chemicals have been released within an enclosed space and the density of the chemicals' vapor may result in significant advective transport of the vapors downward through cracks or openings in floors and into the vadose zone.
- Leaking vapors from natural gas transmission lines.

In each of these cases, the diffusive transport of vapors may be overridden by advective transport and the vapors may be transported in the vadose zone several hundred feet from the source of contamination.

<u>Criteria for Establishing "Boundaries" of the Plumes that Contain Vapor-forming Chemicals</u>. This guidance is intended to be applied to existing groundwater plumes as they are currently defined (e.g., Maximum Contaminant Levels, state standards, or risk-based concentrations). However, it is important to recognize that some non-potable aquifers may have plumes that have been defined by threshold concentrations significantly higher than drinking-water concentrations. In these cases, contamination that is not technically considered part of the plume may still have the potential to pose unacceptable risks via the vapor intrusion pathway. Consequently, the

[48] For assessing the extent of soil gas migration from the subsurface vapor source, it is generally necessary to measure soil gas concentrations, either sub-slab soil gas (preferably) or exterior soil gas with a sufficient density to characterize and understand spatial variability. EPA generally recommends comparing soil gas concentrations to the respective VISLs to establish the boundaries of the vapor intrusion inclusion zone.

plume definition may need to be expanded for purposes of defining an inclusion zone for a vapor intrusion investigation. When groundwater is the subsurface vapor source, EPA generally recommends comparing groundwater concentrations to the VISLs to estimate the boundaries of the plume for purposes of establishing the boundaries of the vapor intrusion inclusion zone.

6.2.2 Prioritizing Investigations with Multiple Buildings

At sites where numerous buildings are potentially subject to vapor intrusion (e.g., developed areas with an extensive plume of contaminated groundwater), it may not be feasible or practical to sample indoor air in each building or soil gas underneath or near each building. In the context of a phased investigation, EPA generally recommends a "worst first" approach to investigating buildings. Factors that may warrant consideration in prioritizing buildings for investigation include:

- <u>Source strength and proximity</u>. Buildings overlying and near a source of vapors in the vadose zone would generally be expected to have a greater potential for vapor intrusion than buildings that do not overlie this same vapor source. Where the subsurface vapor source is groundwater, buildings located over higher concentrations or shallower water levels would generally be expected to have a greater potential for vapor intrusion than buildings located over lower concentrations and deeper groundwater plumes.

- <u>Building types and conditions</u>. Buildings that are continuously occupied may pose a more immediate concern than buildings that are not currently occupied, if all other factors (e.g., source strength and proximity) are equivalent. Nonresidential buildings with bay-style doors that are routinely open may be better ventilated than other types of nonresidential buildings, providing greater potential for dilution of vapor-forming chemicals that enter the building via vapor intrusion.

- <u>Vapor migration ease</u>. Buildings overlying vadose zones made up of coarse geological materials (e.g., gravel, boulders) would generally be expected to have a greater potential for vapor intrusion than buildings overlying vadose zones comprised of fine-grained materials (e.g., silts, slays), provided significant preferential pathways (e.g., geologic fractures, utility corridors) are not present in the fine-grained layers.

Interviews and building surveys during development of the investigation work plan (or during the preliminary analysis – see Section 5) also can provide useful information for prioritizing buildings, when phased testing is chosen or indicated. Sections 6.3 and 6.4 provide additional examples of survey information that can support planning, in addition to supporting data interpretation.

In situations where "higher-priority" buildings and locations are investigated initially, investigation of locations of other buildings may still be warranted, for example, to ensure that the CSM is complete and accurate and that variability in the subsurface conditions and building conditions is understood. There usually is substantial spatial variability in the concentrations of subsurface vapors, caused by heterogeneities in the subsurface materials and other factors that can result in spatial variability in indoor air concentrations. Additionally, building-specific characteristics and occupants' activities that affect building ventilation will vary from building to building, further adding to the temporal variability in indoor air concentrations. Therefore, it may be difficult to identify *a priori* a "representative" or "reasonable worse case" building or group of buildings, when it is determined that sampling all buildings is not practical.

When sampling all buildings is not practical, but other lines of evidence suggest that vapor intrusion may be occurring, the site management team may wish to consider installing engineered exposure controls for vapor intrusion mitigation in buildings without baseline indoor air data (i.e., building mitigation as an early action – see Section 9.0).

6.2.3 Planning for Community Involvement

Community involvement is an important component of any vapor intrusion investigation. EPA generally recommends that a community involvement or public participation plan (see Section 10.1) be developed or refined while planning a vapor intrusion investigation. Proper and sustained community outreach and engagement efforts are critical to effectively implementing work plans for vapor intrusion investigations, particularly when sampling in a home or workplace or on private property is involved. Resuming and conducting community involvement at legacy sites can be particularly complex. The site planning team is highly encouraged to consult with appropriate EPA colleagues experienced in community outreach and involvement efforts and utilize available EPA planning resources, including those discussed in Section 10.0.

6.3 Characterize the Vapor Intrusion Pathway

As discussed in Section 2.0, the vapor intrusion pathway entails emanation of volatile chemicals from a source in a vapor form that migrates in the vadose zone, accumulates underneath building foundations, and enters buildings through openings and conduits. As a result, detailed vapor intrusion investigations designed to develop or enhance the CSM for a specific site will typically address one or more of the following objectives, often in phases:

- Characterize the nature and extent of potential sources of vapors.
- Characterize the migration paths between vapor sources and buildings (potential "receptors").
- Assess building(s) and potential susceptibility to soil gas entry.
- Confirm the presence of a site-related contaminant(s) in the indoor environment.
- Assess the potential contributions of indoor sources to concentrations of hazardous vapors in indoor air.

These objectives are described in the following subsections for purposes of identifying the primary lines of evidence typically developed and evaluated for each objective and describing how the objectives fit together in developing and enhancing the CSM for a specific site and characterizing vapor intrusion potential. This information is provided to assist the site planning team in selecting and sequencing objectives for vapor intrusion investigations. The order of presentation is not intended to convey a suggested sequencing of objectives; rather, it follows the presentation of the conceptual model of vapor intrusion.

6.3.1 Characterize Nature and Extent of Vapor Sources

Investigations to characterize the nature and delineate the extent of potential sources of vapors may rely upon the results of groundwater sampling, soil sampling, or soil gas sampling, as dictated by the site-specific source(s) and subsurface conditions.

Groundwater Sources:

Where contaminated groundwater is a vapor source located near buildings, EPA recommends that groundwater observation wells (i.e., monitoring wells) be installed at strategic locations and used to assess groundwater flow and contaminant concentrations. The extent of groundwater contamination should be verified through groundwater sampling and analysis.[49] Groundwater samples obtained from the uppermost portion of the aquifer that underlies the study area of interest (i.e., where buildings are located) are recommended for establishing representative source concentrations. For this purpose, wells that are screened across the water table interface are preferred and samples should be collected as close as possible to the top of the water table using approved sampling methods designed to minimize loss of volatiles while sampling (EPA 2002a, EPA-ERT 2001a).[50] Ideally, the plume should be shown as stable or shrinking (i.e., is not migrating or rising in concentration, including hazardous byproducts of any biodegradation), through multiple rounds of sampling.

For purposes of assessing vapor intrusion for specific buildings, groundwater samples from wells near buildings are generally recommended over those from distant wells. Interpolation of the results obtained from two or more wells in the uppermost portion of the aquifer may be warranted for these purposes when the spatial pattern suggests significant lateral gradients in contaminant concentrations within the area of interest. However, for purposes of determining whether groundwater poses negligible risk of vapor intrusion on an area-wide basis, it may be more appropriate to utilize sampling results for the most greatly impacted well within the area of interest.

In addition, EPA generally recommends that a soil gas sample be collected immediately above the groundwater table (and above the capillary fringe) (i.e., "near-source" soil gas sample) to help characterize the vapor source.

Vadose Zone Sources:

Where contaminated soil or NAPL in the vadose zone is a vapor source, soil sampling using coring techniques for sample retrieval or using sensors, such as a membrane interface probe, can be used to delineate the extent of contamination. Bulk soil concentration data

[49] Although a soil gas survey can also be employed as a screening tool to assist with the delineation of a plume of contaminated groundwater, EPA recommends that plume delineation ultimately be supported by the collection and analysis of confirmatory groundwater samples at appropriate locations.

[50] If available groundwater data do not meet these criteria, the site data review team should judge whether they are nevertheless representative of potential vapor source concentrations emanating from groundwater.

can be used in a qualitative sense for this purpose. For example, high soil concentrations generally would indicate impacted soil. Unfortunately, the converse is not always true. Non-detect results for soil samples cannot be interpreted to indicate the absence of a subsurface vapor source, because of the large uncertainties associated with measuring concentrations of volatile contaminants introduced during soil sampling, preservation, and chemical analysis.

Alternatively or in addition, a soil gas survey can be used to locate the primary source zone and delineate the areal and vertical extent of the vapor-affected area. Generally, EPA recommends that the soil gas survey include a soil gas sample collected immediately above each contaminant source in the vadose zone (i.e., "near-source" soil gas samples) to help characterize the vapor source.

These sampling options are generally coupled with an understanding of the site-specific subsurface conditions that control the location and extent of contamination (e.g., geologic properties, including stratigraphy and level of heterogeneity; hydrogeologic conditions). Such understanding is generally developed by interpreting the data obtained through borehole logging (i.e., visually inspecting soil cores and determining soil texture) or geophysical tools.

Sample locations should generally be of sufficient density to adequately account for spatial variability and heterogeneity in subsurface conditions. EPA generally recommends consulting with individuals who have expertise in characterizing subsurface environmental conditions (e.g., a geologist) when determining appropriate sampling locations and spacing.

When combined with the data demonstrating that the property reflects the conditions and assumptions of the generic model invoked in the VISLs (see Section 6.5.1), groundwater and "near-source" soil gas samples can be compared to medium-specific screening levels to develop an initial quantitative perspective about the potential level of exposure and risk posed by vapor intrusion. Section 6.5 provides additional information and guidance about risk-based screening of vapor source concentrations.

6.3.2 Characterize Vapor Migration in the Vadose Zone

Investigations seeking to characterize vapor migration in the vadose zone generally entail, at a minimum, a soil gas survey. Because soil gas concentrations can exhibit considerable spatial variability,[51] EPA generally recommends that soil gas surveys collect soil gas samples at multiple locations and depth intervals between the vapor source and buildings (potential "receptors"). The soil gas survey may include samples collected immediately outside the building ("exterior soil gas") at various depths or several depth intervals, as well as immediately

[51] Modeling of idealized scenarios provides additional demonstrations about spatial variability of soil gas concentrations. For example, vertical profiles of soil gas concentration can be very different underneath buildings compared to locations exterior to the building and soil gas concentrations may not be uniform laterally, particularly in the vicinity of the building, even when the vapor source is a laterally extensive plume of contaminated groundwater (EPA 2012b). These simulation results indicate why EPA recommends that soil gas generally be sampled in multiple sampling locations, when assessing subsurface vapor migration pathways.

beneath it (sub-slab soil gas sampling).[52] Where applicable, crawl space air sampling may be conducted.

Generally, EPA recommends that the soil gas survey include a "near-source" soil gas sample collected immediately above each source of contamination to help characterize the vapor source (see Section 6.3.1). If any shallow soil gas samples are collected, EPA recommends they be collected as close as possible to the building and at depths below the respective building foundation and no less than five feet below ground surface, depending on site-specific conditions.

To characterize subsurface migration in the vadose zone, soil gas survey data are generally coupled with an understanding of the site-specific subsurface conditions that influence vapor migration and attenuation (e.g., geologic properties, including stratigraphy and level of heterogeneity; hydrologic conditions, including groundwater elevation and soil moisture; and biological properties, including availability of oxygen to support aerobic biodegradation).[53] Such geologic understanding is generally developed by interpreting the data obtained through borehole logging and geophysical tools. Hydrologic conditions can be characterized by analyzing soil samples for porosity and moisture content and by hydrologic modeling. An intensive soil gas survey to establish current vertical profiles for contaminant vapors and oxygen (and, in some cases, biodegradation products) may be able to demonstrate that biodegradation is responsible for attenuating vapor migration to a greater extent than can be attributed to advection and diffusion in the vadose zone.[54]

When conducted contemporaneously for multiple buildings, a soil gas survey and characterization of the vadose zone can help identify distances from subsurface vapor sources beyond which threats from vapor intrusion are not reasonably expected, as mentioned in Section 6.2.1. At sites with a limited number of potentially affected buildings, it may be feasible to characterize the subsurface vapor migration near and surrounding all of them. However, at sites where a large number of buildings may be affected, this approach is not likely to be feasible; in these cases, EPA generally recommends that the site manager seek the advice of a geologist familiar with the site-specific subsurface conditions to help guide selection of appropriate sampling locations and assess whether "representative" or "reasonable worse case" locations can be identified, as appropriate to the objectives of the investigation. Because there usually is substantial spatial variability in the concentrations of subsurface vapors, caused partially by heterogeneities in the subsurface materials, it may be difficult to identify *a priori* locations that are either "representative" or are "reasonable worse case" subsurface conditions.

[52] Spacing of soil gas sampling locations should generally consider the extent and location of the subsurface vapor source, distance between the building and the source, and other site-specific factors.

[53] As noted in Section 2.0, vapor migration in the vadose zone can be impeded by several factors, including soil moisture, low-permeability (generally fine-grained) soils, and biodegradation. Significant characterization of the vadose zone may be needed to demonstrate that the applicable geologic, hydrologic, and biologic features are laterally extensive over distances that are large compared to the size of the building or the extent of vapor contamination at a specific site.

[54] In this context, mathematical modeling can be employed to characterize vapor migration attributable to advection and diffusion in the vadose zone.

Subsurface investigations of vapor intrusion should also generally include an evaluation of utility corridors, which can facilitate unattenuated vapor transport over longer-than-anticipated distances or migration of NAPLs towards and into buildings that are serviced by the utility. Public and facility records are often useful sources of information about utility locations, which may provide maps, "as built diagrams," or construction specifications. Depending upon the CSM, sampling of vapors within the utility corridor (or within a sewer, if applicable) may be warranted to characterize vapor migration in the subsurface (or characterize a secondary source of vapors – see Sections 6.3.1 and Section 2.1).

When combined with other data, as discussed further in Section 7.3, information about subsurface vapor migration can support determinations that the vapor intrusion pathway is complete under current conditions or may be complete under future conditions. When combined with other lines of evidence, information about subsurface vapor migration can support determinations that the vapor intrusion pathway is not complete under current conditions, as discussed further in Section 7.3.

When evaluating subsurface vapor migration and attenuation in locations where buildings do not exist, it is important to recognize that the conditions in the vadose zone and subsurface vapor concentrations may be changed as a result of constructing a new building and/or supporting infrastructure. For example, the moisture content may decrease and the moisture profile change in the vadose zone as a result of reduced infiltration of rainwater. The permeability to vapor flow in the vadose zone may be altered in the foundation vicinity due to construction. Finally, the future presence of extensive surface covers and/or utility corridors may also modify the vertical and horizontal profile of vapor concentrations in the subsurface. As a result, EPA recommends that lines of evidence in addition to a soil gas survey (e.g., modeling) be developed and considered to support any determination that a future building will not be subject to vapor intrusion or will not pose unacceptable health risks for occupants. Owing to the potentially unpredictable plans for building construction and site redevelopment, as well as potentially unpredictable changes in the transitory soil characteristics (e.g., soil moisture) and subsurface vapor concentrations, institutional controls (e.g., to require a confirmatory evaluation of the vapor intrusion pathway when new buildings are constructed) may be warranted for this situation.

6.3.3 Assess Building Susceptibility to Soil Gas Entry

When elevated concentrations of vapor-forming chemicals accumulate in the soil gas immediately underneath the foundation, surrounding the basement, or within the crawl space of a vulnerable building, then soil gas entry (i.e., vapor intrusion) can lead to unacceptable levels of subsurface contaminants in indoor air. As discussed in Section 2.3, soil gas can enter a building when vapor entry routes are present and driving forces favor advection of air from the subsurface into indoor air. Single-family detached homes can generally be presumed susceptible to soil gas entry, unless a mitigation system (e.g., radon mitigation system) is present and operating as intended.

EPA recommends that more than one line of evidence be employed to assess susceptibility to soil gas entry, when this objective is selected as part of a site-specific investigation plan for vapor intrusion assessment. Vulnerability to soil gas entry can be assessed for a specific building by using any of several methods, including:

- Concurrently monitoring indoor air samples for presence of radon and finding radon in indoor air at levels greater than outdoors.[55]

- Employing a photoionization detector (PID) or other real-time in-field device, capable of detecting parts per billion by volume (ppbv) levels, to directly survey suspected locations of soil gas entry (e.g., utility penetrations, sumps) and finding elevated readings of vapors.

- Conducting a visual inspection for cracks and holes in concrete foundation slabs or basement walls. (Openings for soil gas entry will not necessarily be visible or accessible for inspection, so the absence of visible openings, by itself, is insufficient to demonstrate that a building is not susceptible to soil gas entry.)

- Monitoring pressure differences between the building and subsurface environment to assess the effects of the heating, ventilation, and air-conditioning (HVAC) systems.

- Injecting tracers, such as sulfur hexafluoride or helium, into the subsurface at selected concentrations and subsequently finding it in indoor air samples.

Certain complementary information obtained for the building, as identified in Section 6.4.1, can also support such assessments. Relevant information includes the operating characteristics of HVAC systems.

In many commercial buildings, the HVAC system brings outdoor air into the building, potentially creating building over-pressurization relative to the outdoor environment. When the building is over-pressurized, vapor intrusion potential is diminished because a driving force for soil gas entry should not exist over at least a portion of the building foundation.[56] When the subsurface vapor sources underneath or near such buildings have significant potential to pose a vapor intrusion threat, it may be useful to assess susceptibility to soil gas entry and diagnose vapor intrusion (see Sections 6.3.4 and 6.4.1) in such buildings under conditions when the HVAC system is not operating. (In addition, indoor air testing could be conducted during periods when the HVAC system operates with diminished flows, such as weekends or evenings.) The results of such testing can be used to support decisions about building mitigation, monitoring, and institutional controls as part of a vapor intrusion remedy. For example, if the results indicate susceptibility to soil gas entry when the HVAC system is not in operation and vapor intrusion under these conditions has the potential to pose a health concern, then the building may warrant engineered exposure controls and/or future monitoring (e.g., continuous monitoring of

[55] Naturally occurring radon may serve as a tracer to help identify those buildings that are more susceptible to soil gas entry than others. Buildings with radon concentrations greater than levels in ambient air are likely susceptible to soil gas intrusion and would likely be susceptible to other subsurface vapors. On the other hand, the radon concentration in a building is <u>not</u> generally expected to be a good quantitative indicator of indoor air exposure concentrations of vapor-forming chemicals. Hence, radon measurement is not generally recommended as a proxy for directly measuring vapor-forming chemicals in indoor air. Among other factors, the distribution of radon-emanating rock and soil and the spatial and temporal variability of their source strength are generally expected to be very different than the distribution and source strength variability for subsurface sources of chemical vapors.

[56] Over-pressurization may not be uniform throughout a building, particularly in large buildings. It should not be assumed that any over-pressurization in portions of a building will necessarily mitigate all openings for soil gas entry.

the pressure gradient across the foundation or indoor air testing), which may be enforceable through an IC (see Section 8.6). Similarly, buildings with pre-existing radon mitigation systems, which overlie or are near subsurface vapor sources, could be tested under conditions where the radon mitigation system is not operated to support decisions about building mitigation, monitoring, and institutional controls as part of a vapor intrusion remedy.

6.3.4 Evaluate Presence and Concentration of Subsurface Contaminants in Indoor Air

Indoor air sampling (see Section 6.4.1) using time-integrated sampling methods or grab samples can confirm the presence, if any, of a site-related, subsurface contaminant(s) in the indoor environment. When combined with data characterizing subsurface vapor migration and demonstrating the building is (or is not) susceptible to soil gas entry, indoor air sampling data can support determinations that the vapor intrusion pathway is (or is not) complete for a given building, as discussed further in Section 7.3. When conducted contemporaneously in multiple buildings, indoor air sampling can, in concert with soil gas survey data and data delineating subsurface vapor sources, help identify the boundaries of "vapor intrusion inclusion zones" (i.e., neighborhood areas within which buildings are known or suspected to have indoor air concentrations of subsurface contaminants arising from vapor intrusion (see Section 6.2.1)).

Indoor air sampling is most commonly conducted using time-integrated sampling methods to estimate exposure concentrations for building occupants, which may include contributions from "indoor" or ambient air sources of these chemicals (see Section 2.5). For example, time-integrated concentrations of hazardous vapors in samples of indoor air can be compared to appropriate, risk-based screening criteria (see Section 6.5) to support inferences about risks posed by vapor-forming chemicals found in the subsurface environment.[57]

When sampling indoor air or sub-slab soil gas to estimate exposure concentrations arising from vapor intrusion, EPA generally recommends removing potential indoor sources of vapor-forming chemicals (see Section 2.5 and 6.4.1) from the building to strive to ensure that the concentrations measured in the indoor air samples are attributable to the vapor intrusion pathway. However, even after removing indoor sources, their effects may linger depending on source strength, relative humidity in the building, and the extent to which the contaminants have been absorbed by carpets and other fabrics or "sinks." In addition, field experience suggests that it may not be possible to remove all indoor sources. It may be particularly impractical to do so in industrial settings where vapor-forming materials are used or stored.

6.3.5 Identify and Evaluate Contributions from Indoor and Ambient Air Sources

To support evaluations of sources of indoor air concentrations, EPA recommends that the CSM identify known or suspected indoor sources of the volatile chemicals also found in the subsurface (see Section 2.5) and characterize ambient air quality (see Section 6.4.2) in the site vicinity for these same chemicals. Key supporting information includes: (1) the locations and

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[57] In certain cases, depending in part on the results (e.g., concentrations exceed risk-based screening levels), indoor air sampling data may be a sufficient basis for supporting decisions to undertake pre-emptive mitigation/early action (see Section 9.0) in lieu of additional rounds of sampling and analysis or an evaluation of the contribution of background sources to indoor air concentrations.

types of known or potential indoor sources; (2) information about outdoor sources, such as nearby commercial or industrial facilities and mobile sources (e.g., cars, trucks, and other equipment); and 3) data on the local ambient air quality.

Grab (essentially short-duration) samples of indoor air, as described in Section 6.4.1, can be useful for identifying indoor sources of vapors. Indoor air concentrations obtained using time-integrated sampling methods are generally needed, however, to distinguish contributions to indoor air concentrations from vapor intrusion versus indoor and ambient air sources.

If the subsurface vapor sources are comprised of multiple vapor-forming chemicals and the subsurface source and distribution for these chemicals are similar, then time-integrated sampling methods can be used to determine whether concentrations of hazardous vapors in indoor air are primarily due to indoor sources. Specifically, concurrent sub-slab soil gas can be collected with indoor air samples.

> Results indicating vapor intrusion as primarily responsible for indoor air concentrations. The predominant vapor-forming chemicals and their relative proportions in indoor air and sub-slab vapor samples would be expected to be similar and their concentrations in sub-slab soil gas would be expected to be higher than in indoor air, if vapor intrusion is primarily responsible for indoor air concentrations. If recalcitrant (i.e., not subject to biodegradation in the vadose zone), the predominant vapor-forming chemicals and their relative proportions in the subsurface vapor source should also be similar if vapor intrusion is primarily responsible for indoor air concentrations.

> Results indicating indoor sources as primarily responsible for indoor air concentrations. Conversely, if significant concentrations of a contaminant are detected in indoor air, but are not present or barely present in sub-slab soil gas samples (or representative samples of the subsurface vapor source), then the presence of this contaminant in indoor air may not arise from the vapor intrusion pathway, but rather from indoor sources or other background sources.

Likewise, concurrent outdoor (ambient) air samples can be collected, in addition to indoor air samples. If the predominant vapor-forming chemicals and their relative proportions in indoor air and outdoor (ambient) air are similar, then vapor intrusion may not be primarily responsible for indoor air concentrations (particularly if the predominant vapor-forming chemicals and their relative proportions in the subsurface vapor source (e.g., groundwater or soil) are dissimilar).

Current levels of volatile chemicals in ambient air and in indoor air due to indoor and ambient air sources may be lower than those observed historically, due to regulations and business practices fostering less use of toxic, vapor-forming chemicals in consumer products and industrial processes. As a result, EPA does not recommend the use of generic values of historic background concentrations, even those cited in peer-reviewed publications, to characterize current levels in any building. Rather EPA recommends that site-specific data (e.g., sub-slab, indoor air and ambient air sampling data) be obtained, and evaluated, as described above, when the investigation objectives include demonstrating that indoor air concentrations arise from indoor or ambient air sources.

On the other hand, if measured indoor air concentrations are found to greatly exceed the historic range of background levels, there is a greater likelihood that the indoor air concentrations are the result of vapor intrusion. EPA has compiled and published an evaluation of studies pertaining to indoor air concentrations of volatile organic compounds in North American residences in 1990-2005 (EPA 2011a), which can be employed to identify whether measured indoor air concentrations are in the historic range of background concentrations; if so, then EPA recommends planning additional site-specific investigations aimed at distinguishing between vapor intrusion and indoor and ambient air as contributors to indoor air concentrations.

6.3.6 Select, Prioritize, and Sequence Investigation Objectives

Site-specific investigations of potential vapor intrusion frequently begin with pursuing one or more of the foregoing objectives presented in Sections 6.3.1 through 6.3.5. Criteria potentially warranting consideration by the site planning team when making decisions about prioritizing and sequencing investigation objectives include: site scenario (see Section 6.1); data gaps in the CSM (see Section 5.4); and relationships with and perspectives of the owners and occupants of potentially impacted buildings.

Characterizing vapor sources (Section 6.3.1), characterizing subsurface vapor migration (Section 6.3.2), and evaluating the presence of subsurface contaminants in indoor air (Section 6.3.4) – are frequently candidates for an initial objective and each can be pursued separately. For example, characterizing vapor sources (Section 6.3.1) may be a useful initial choice when responding to an initial report about a release of hazardous, vapor-forming chemicals to the subsurface from a commercial or industrial operation or when buildings do not exist currently, but are expected in the future. Characterizing vapor sources may also be a useful initial choice when building owners or occupants are reluctant to grant access for indoor air testing. In this situation, the site planning team may need to pursue subsurface investigations more intensely to characterize vapor intrusion potential before being granted building access. When responding to reports of odors in buildings or addressing vapor intrusion for the first time as part of a periodic review of a remedial or corrective action for contaminated groundwater, testing indoor air (Section 6.3.4) may be a useful initial objective. In a different scenario, characterizing subsurface vapor migration (Section 6.3.2) may be a useful starting point when addressing sources that are comprised of potentially biodegradable chemicals or that are suspected to occur below an extensive geologic layer that might impede upward diffusive migration. For large buildings with HVAC systems that may over-pressurize the interior relative to the subsurface environment, EPA generally recommends: a building assessment early in the investigation, which obtains and weighs the complementary information identified in Section 6.4.1, to support investigation planning; and an evaluation of susceptibility to soil gas entry under conditions when the HVAC system is not operating (see Section 6.3.3).

The investigation objectives described in Sections 6.3.1 through 6.3.5 may, in some cases, be conducted iteratively with increasing complexity as the investigation proceeds and the CSM is refined. For example, grab (essentially short-duration) samples of indoor air, as described in Section 6.4.1, can be useful for identifying indoor sources of vapors while potential background sources (e.g., household or commercial cleaning products) are surveyed and before indoor air is tested using time-integrated sampling methods to estimate exposure concentrations. More advanced methods of distinguishing contributions to indoor air might be utilized in intermediate phases of the investigation under such an iterative approach.

6.4 General Principles and Recommendations for Sampling

Sampling of indoor air, outdoor air, soil gas, and groundwater and analysis for vapor-forming chemicals can play an important role in vapor intrusion investigations for one or more of the objectives identified in Section 6.3. This subsection summarizes for indoor air, outdoor air, sub-slab soil gas, exterior soil gas, and groundwater the following:

- Principal methods for collecting samples.
- Potential uses of the resulting sampling data.
- Recommended practices for sample collection.
- Unique or frequently encountered logistical issues.

Soil and NAPL sampling also may be used to characterize the nature and extent of subsurface vapor sources (see Section 6.3.1). Information about soil sampling can be found in EPA-ERT (2001b). However, because of the large uncertainties associated with measuring concentrations of volatile contaminants introduced during soil sampling, preservation, and chemical analysis, bulk soil (as opposed to soil gas) sampling and analysis is not currently recommended for estimating the potential for vapor intrusion to pose unacceptable health risks in indoor air. In addition, there are uncertainties associated with soil partitioning calculations.

EPA recommends that the site planning team ensure that the sampling data will meet the site-specific data quality needs. This entails ensuring that the sampling and analytical methods are capable of obtaining reliable analytical detections of concentrations less than project-appropriate, risk-based screening levels (e.g., VISLs). It can also entail identifying and utilizing appropriate sampling locations and durations and addressing spatial and temporal variability to fulfill the specific objectives of the investigation, which may include obtaining data to characterize the potential human exposure in a building(s). The number and types of samples used at a specific site should be decided by the planning and data review team based on the CSM, the objectives of the investigation, and other site-specific information.

The sampling duration depends on the type of medium being sampled (for example, soil gas, sub-slab soil gas, and indoor or outdoor air) and analytical methods (for example, Method TO-15). Some of the key recommended considerations are provided in the following subsections. Several rounds of sampling are often needed to develop an understanding of temporal variability.

6.4.1 Indoor Air Sampling

Indoor air sampling results: are needed to assess the presence and level of risk posed by vapor-forming chemicals in indoor air (see Sections 6.3.4 and 7.4); and can be useful in diagnosing whether vapor intrusion is occurring (see Sections 6.3.3, 6.3.5, and 7.3). These two uses of indoor air sampling in vapor intrusion investigations are discussed further below with recommended methods for each. As discussed further in Sections 8.4 and 8.7, indoor air sampling may also be useful for supporting performance evaluations of vapor intrusion mitigation systems and verifying the health protectiveness of subsurface remediation systems.

A potential shortcoming of indoor air testing is that indoor sources and outdoor sources unrelated to subsurface contamination – "background" – may contribute to the presence of volatile chemicals in occupied buildings (see Section 2.4), particularly if these sources cannot be removed from the building prior to sampling indoors. This shortcoming of indoor air testing is unavoidable when the subsurface environment contains the very same volatile chemicals that originate in indoor air due to background sources, which is common for some chemicals and relatively rare for others (EPA 2011a). In this circumstance, additional lines of evidence, possibly including special procedures and analyses, should be evaluated to distinguish background contributions from those originating from vapor intrusion (see Section 6.3.5).

After discussing recommended sampling methods and practices for the primary uses of indoor air sampling data, this sub-section concludes by discussing:

- Recommended measures to reduce the impact of indoor sources of vapor-forming chemicals.
- Recommended approach to establishing analyte lists for indoor air samples.
- Complementary, building-specific data that can be collected contemporaneously while indoors.

Estimate Human Exposure Levels. Indoor air sampling and analysis provide the most direct approach to estimating concentrations of toxic, volatile chemicals in indoor air to which building occupants can be exposed. For these purposes, time-integrated sampling methods are generally recommended for indoor air, since indoor air concentrations can be temporally variable within a day and between days, seasons, and years.

For many years, evacuated canisters have been the industry standard for collecting time-integrated samples. Typically, indoor air samples are collected over a 24-hour period in residences or over an 8-hour period (or workday equivalent) in commercial and industrial settings, when using these devices.[58] Although passive diffusion samplers have been less commonly used to quantify indoor air concentrations, their use may grow as a result of recent demonstrations that they can yield results comparable to those obtained using evacuated canisters (EPA-Region 9 2010; EPA 2012g; Odencrantz et al. 2009; Odencrantz et al. 2008), and a recognition that they may be less intrusive for some building owners and occupants and more convenient for field staff (EPA-Region 9 2010). Passive diffusion samplers are also capable of being deployed for longer durations than evacuated canisters, thereby providing a more economic means of obtaining average indoor air concentrations over longer periods of exposure.

For a typical-size residential building or a commercial building less than 1,500 square feet, EPA recommends that the site teams generally collect one time-integrated sample in the area directly above the foundation floor (basement or crawl space) and one from the first floor living or

[58] Two (or more) large canisters can be connected together to allow collection of time-integrated samples over longer durations, which is generally desirable for estimating long-term average exposure levels.

occupied area, at least for the initial sampling round. In general, samples should be collected at the breathing zone level for the most sensitive exposed population.

Situations that should trigger discussions about the number of sample locations per building include: (1) very large homes or buildings;[59] (2) multi-use buildings, particularly ones with segmented areas that are occupied by different populations (e.g., day care with young children versus office with adult workers) or have different occupancy patterns over time. Additional samples may be warranted, depending on internal building partitions, HVAC layout, contaminant distribution in the subsurface, and occurrence of observable locations of potential soil gas entry (e.g., basement sumps or drains, relatively large holes or spaces in the foundation floor, entry points for utilities). Closed rooms located below ground may have appreciably higher contaminant concentrations originating from vapor intrusion. Closed rooms may warrant sampling to characterize the reasonably maximum exposure levels, if occupied, or to diagnose vapor intrusion (e.g., see below), even if not occupied.

More than one round of indoor air sampling is generally recommended in order to characterize exposure levels in indoor air, because of the temporal variability of indoor air concentrations, which reflects time-dependent changes in soil gas entry rates, exchange rates, intra-building mixing, among other factors. Also, multiple sampling events generally are considered necessary to account for seasonal variations in climate and changes in the habits of building occupants.[60] In many geographic areas, indoor air sampling during the heating season, when stack effects are generally more significant, may yield higher indoor air concentrations than at other periods. Another scenario that may yield higher indoor air concentrations is when a building is sealed and the ventilation system is not operating.

When sampling indoor air or sub-slab soil gas, EPA generally recommends removing potential indoor sources of vapor-forming chemicals (see Section 2.5) from the building to strive to ensure that the concentrations measured in the indoor air samples are attributable to the vapor intrusion pathway. Field experience in residential settings suggests that it may not be possible to remove all sources. It may be particularly impractical to do so in industrial settings where vapor-forming materials are used or stored. After removal of indoor sources, their effects may linger longer depending on source strength, relative humidity inside the building, and the extent to which the contaminants have been absorbed by carpets and other fabrics or "sinks." In residential settings, EPA generally recommends that potential indoor sources be removed from the structure and stored in a secure location at least 24 to 72 hours prior to the start of sampling, based on an approximate air exchange rate of 0.25 to 1.0 per hour in residential buildings.

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[59] Larger commercial and residential buildings (e.g., multi-family residences) may require additional discussion with the site planning team and perhaps a statistician to select the appropriate number and placement of indoor air samples to meet DQOs.

[60] More than one round and often several rounds are needed to develop an understanding of temporal variability of indoor air concentrations. Given EPA's over-arching duty to protect human health and the disruption to building owners and occupants caused by indoor air sampling, risk managers may choose to pursue pre-emptive mitigation (i.e., early action) at some buildings (see Section 9.0) rather than, for example, conduct multiple rounds of sampling over a few years to establish a better estimate of long-term average exposure concentration.

Diagnose Vapor Intrusion and Background Sources. When access is granted for indoor air sampling, EPA generally recommends concurrently collecting sub-slab soil gas and outdoor (ambient) air over similar durations using the same methods. Comparing these results to each other and to results for subsurface vapor sources can foster insights and support findings about the relative contribution of vapor intrusion and background sources to indoor air concentrations (as described in Section 6.3.5). In this case, time-integrated sampling methods are generally recommended for indoor air, because concentrations of vapor-forming chemicals can vary significantly over time.

Grab (essentially short-duration) samples of indoor air can, however, be useful for confirming the presence of a subsurface contaminant in indoor air (see Section 6.3.4), identifying indoor sources of vapors (see Section 6.3.5), and identifying openings for soil gas entry into buildings (see Section 6.3.3). These samples can be analyzed with EPA's mobile Trace Atmospheric Gas Analyzer (TAGA), field-portable gas chromatographs, or mass spectrometers (EPA-ERT 2012). For identifying indoor sources or openings for soil gas entry, one round of grab sampling of indoor air may be sufficient. Grab samples can also provide a convenient and less intrusive means of confirming the presence, if any, of a site-related, subsurface contaminant(s) in the indoor environment. For this purpose, EPA generally recommends collecting one sample directly above the foundation floor (basement or crawl space) and one from the first floor living or occupied area.

An individual grab sample is not reliable, however, for purposes of demonstrating that vapor intrusion is not occurring in a specific building, because indoor air concentrations can exhibit significant temporal variability. In general, EPA recommends collecting multiple time-integrated samples to support any such building-specific determination.

Indoor air samples can also be concurrently collected for radon testing, which may be useful in evaluating building susceptibility to soil gas entry (see Section 6.3.3).

Evaluate and Develop Analyte Lists. EPA recommends the site planning and data evaluation team limit chemical analyses to those vapor-forming chemicals known (based upon subsurface contaminant characterization) or reasonably expected (based upon site history) to be present in the subsurface environment. For example, if the site history and reliable subsurface sampling data do not identify benzene as a subsurface contaminant, it would be appropriate for site managers to exclude benzene as a target analyte for indoor air samples. Benzene could originate indoors as a result of a car, lawnmower, or snow blower in a garage. In this hypothetical case, benzene would not typically be amenable to reduction by vapor mitigation systems or subsurface remediation efforts. In fact, requesting an extensive list of analytes that are not related to subsurface contamination may unnecessarily complicate risk communication if indoor air testing reveals volatile chemicals unrelated to vapor intrusion.

Collect Complementary Data While Indoors. EPA recommends that the following complementary data be gathered by observation, interviews, or reports (e.g., mechanical test-and-balance reports) while buildings are sampled to analyze indoor air:

- Building Occupancy

- Characteristics and locations of building occupants (e.g., residents, including children; expectations for presence of general public in commercial or industrial settings; presence of multiple exposure units – due to different uses or activities and occupants – within a building).

- Hours of building occupancy under current conditions (and reasonably expected future conditions, as appropriate), particularly for a nonresidential setting. This information is pertinent to the risk assessment and data evaluation and should generally factor into the sampling duration needed to represent indoor air exposure.

• Susceptibility to Soil Gas Entry Under Current Conditions

- Presence and operation of a mitigation system, which would generally be expected to mitigate intrusion of vapor-forming chemicals even if designed for radon.

- Physical conditions that indicate potential openings to soil gas entry (e.g., potential conduits, such as cracks or floor drains; presence of structures such as utility pits, sumps, and elevators; basements or crawl spaces; modifications to the original foundation).

- Any areas with significant under-pressurization, relative to the outdoors. (As noted in Section 2.3, building under-pressurization relative to the subsurface provides a driving force for soil gas entry.)

• Building Ventilation, Heating, and Cooling

- Building ventilation, including zones of mechanical influence and stagnation. As noted in Section 2.3, greater ventilation typically results in smaller vapor concentrations in indoor air. Any non-ventilated or passively ventilated rooms (such as mechanical rooms) may be subject to greater accumulation of vapors. For commercial and industrial buildings, each distinct zone of influence may warrant sampling, when indoor air testing is selected as part of a site-specific investigation plan for vapor intrusion assessment.

- Operating characteristics of HVAC systems. In many commercial buildings, the HVAC system brings outdoor air into the building, potentially creating building over-pressurization relative to the outdoor environment. Any areas with significant over-pressurization, relative to the outdoors, should be noted.

• Indoor and Outdoor Sources of Vapor-Forming Chemicals

- Chemicals and consumer products used or stored within the building that can act as potential sources of toxic vapors. Vapor-forming chemicals are used in many commercial and most industrial buildings. As noted in Section 2.5, consumer products that can emit vapors may be common in residential buildings. In some circumstances, a PID, capable of detecting ppbv levels, can be used to directly survey the building for locations with vapor-forming chemicals and materials; however, the PID may not be sensitive enough for very low concentration sources. More sensitive options may include use of the HAPSITE gas chromatograph/mass spectrometer or the TAGA Mobile Laboratory (EPA-ERT 2012).

- HVAC systems that bring outdoor air into the building potentially bring contaminated outdoor air into the building, depending on the location of the vent and exhaust with regard to other spaces. For example, HVAC intakes adjacent to or near a dry-cleaning facility may introduce toxic vapors of the dry-cleaning solvent into the building.

- Presence and operation of any indoor air treatment system (e.g., in-line carbon adsorption) that can reduce indoor exposure levels of vapor-forming chemicals.

In general, EPA recommends that the complementary information be collected during investigation planning and scoping to help decide where to sample and prioritize or sequence buildings for testing. Then, the information can be confirmed during indoor sampling.

In some cases, contaminated groundwater seeps into or actively collects in the building (for example, in sumps), possibly serving as a direct source of vapors. It may be appropriate to collect water samples concurrently with indoor air (and any sub-slab) samples in these circumstances.

6.4.2 Outdoor Air Sampling

Outdoor air concentration data can be useful in identifying potential contributions to indoor air concentrations from ambient air sources (see Section 6.3.5). Therefore, EPA generally recommends collecting ambient air samples using similar sampling and analysis methods, whenever indoor air samples are collected. Normally, one or two outdoor air sample locations should be sufficient to characterize the conditions surrounding a single or a few buildings.[61] Additional outdoor air samples may be warranted if the investigation is assessing multiple buildings over a wide area. Sample locations should be designed to characterize representative conditions in the absence of site-related subsurface contamination (i.e., avoid collecting ambient air samples near locations of known or suspected chemical release(s), including any atmospheric releases from remediation equipment). It also is suggested that observable potential outdoor sources of pollutants (e.g., air emissions from nearby commercial or industrial facilities) be recorded during all building surveys.

EPA recommends that ambient air samples generally be collected over the same sampling period as indoor air so contaminant concentrations can be compared between media. To facilitate such a comparison for residential buildings, EPA generally recommends beginning ambient air sampling at least one hour, but preferably two hours, before indoor air monitoring

[61] For buildings where outdoor air is mechanically brought into the building, an outdoor sample may be co-located near the HVAC intake.