SUMMARY REPORT

SERDP and ESTCP Workshop on Vapor Intrusion into Indoor Air from Contaminated Groundwater

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ACRONYMS

BPR	building pressure recycling
DoD	Department of Defense
ESTCP	Environmental Security Technology Certification Program
FAQ	frequently asked questions
ITRC	Interstate Technology & Regulatory Council
LCA	life-cycle assessment
RPM	remedial program manager
SERDP	Strategic Environmental Research and Development Program
USEPA	U.S Environmental Protection Agency
VI	vapor intrusion
VOC	volatile organic compound

1.0 INTRODUCTION

The Strategic Environmental Research and Development Program (SERDP) and the Environmental Security Technology Certification Program (ESTCP) are the Department of Defense's (DoD) environmental research programs (herein referred to as "The Programs"), harnessing the latest science and technology to improve DoD's environmental performance, reduce costs, and enhance and sustain mission capabilities. The Programs fund basic and applied research as well as field demonstration and validation efforts addressing DoD's most prevalent environmental needs. For additional information, refer to www.serdp-estcp.org.

The "*Workshop on Vapor Intrusion into Indoor Air from Contaminated Groundwater*" was sponsored by The Programs and held in Tempe, Arizona on 19 December 2013. The goal of the workshop was to develop a path forward for investments and technology transfer by SERDP & ESTCP in vapor intrusion assessment. Specific questions to answer included:

- What additional research is warranted in this area, if any?
- Are there additional technology or methodology demonstrations needed to move the field forward to implementation of key concepts?
- What interactions need to take place with the end users?
- Are additional guidance documents, training, and or seminars needed?

The workshop's agenda focused on the research needed to deal more efficiently with the characterization and mitigation of sites impacted by contaminant vapor intrusion, with overall objectives to:

(1) Review the current status of The Programs' funded efforts on vapor intrusion, and
(2) Discuss future research and demonstration needs to improve our ability to properly assess the vapor intrusion pathway and indoor air concentrations.

Approximately 25 invited experts representing DoD remedial program managers (RPMs), state regulators, engineers, academic researchers, and consultants attended the workshop. The agenda from the workshop is found in Appendix A, and the attendee list is provided in Appendix B. A steering committee composed of representatives from the various sectors assisted The Programs in defining the meeting's scope and format. Members of the steering committee included Paul Johnson, Ph.D. (Arizona State University), Marvin Unger, Ph.D. (HydroGeoLogic, Inc.), and Hans Stroo, Ph.D. (Stroo Consulting LLC). The Steering Committee was led by Andrea Leeson, Ph.D., the SERDP & ESTCP Deputy Director as well as the Program Manager for the Environmental Restoration program area.

The agenda was designed to identify the most pressing needs in a focused manner, while allowing all participants to express their views and operational requirements. The workshop opened with presentations summarizing efforts supported to date by the Programs to address research and demonstration needs at vapor intrusion sites; the presentations also reflected the state of the science and practice. Since 2004, The Programs have funded several projects (ER-200423, ER-200702, ER-200707, ER-200830, ER-201025, ER-201119 and ER-201322) in an effort to understand vapor intrusion processes, develop low cost alternatives for sampling and

analysis, and validate cost effective methods for mitigating radon and volatile organic compound (VOC) subsurface vapor intrusion. These projects have determined that vapor concentrations can be highly variable in space and time, and they have validated improved vapor intrusion field investigation methods, including use of on-site analytical equipment to rapidly identify and evaluate vapor intrusion impacts. Summaries of these vapor intrusion projects can be found at: http://serdp.org/Featured-Initiatives/Cleanup-Initiatives/Vapor-Intrusion. This work has established a defensible technical foundation for improved vapor intrusion protocols.

Following the presentations, the participants were assigned to specific breakout session groups based on each individual's expertise. The goal was to have a varied mix of expertise in each of the four (4) breakout groups, as each group was tasked with discussing the current state of the science for the following four technical topics: (1) spatial and temporal variability, (2) predictive modeling, (3) characterization and long term monitoring, and (4) mitigation system development. Each breakout group discussed data gaps and technology needs where additional research and development or field demonstrations would improve the understanding and assessment of the vapor intrusion processes and associated mitigation approaches. Each breakout session identified research, demonstration, and technology transfer needs for the long-term management of vapor intrusion sites, built on the earlier discussions and presentations.

Following the breakout sessions, the entire group reconvened to participate in final discussions focused on identifying the key issues and the priority research, demonstration, and technology transfer needs. These discussions resulted in the identification of the needs presented in Section 2 (Research Needs) and Section 3 (Technology Transfer Needs) of this report. Several of the participants contributed by drafting and/or editing those sections of this report.

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2.0 RESEARCH AND DEMONSTRATION NEEDS

2.1 Decision-Support Tools and Guidance on Vapor Intrusion Assessments and Mitigation

Vapor intrusion impacts to specific buildings can be difficult to predict or even measure accurately. Key uncertainties associated with pathway assessment include the location and strength of subsurface sources, the degree of spatial and temporal variability, and the existence, location and significance of any preferential vapor migration pathways. As a result of these uncertainties, conventional multiple lines-of-evidence vapor intrusion investigations can consume enormous time and resources, they might not lead to the right conclusion and actions, and they can result in considerable public concern.

There is a critical need to develop and demonstrate tools and guidance needed to make robust decisions quickly and cost-effectively at vapor intrusion sites. Such guidance should include decision diagrams and detail the lines of evidence required, and should also help managers understand and manage the inevitable uncertainty involved in vapor intrusion assessments. They may also allow for use of other metrics beyond indoor air concentrations (e.g., measurement of vapor mass flux in the subsurface) and expanded alternatives for vapor intrusion mitigation (e.g., building pressurization).

Workshop participants identified two high priority needs, which are listed in italics below, along with brief rationales and discussions for each.

1. *Cost-effective and defensible prediction and data reduction methods that consider both temporal and spatial variability, and that are practicable for assessing potential health risks from vapor intrusion and/or determining if mitigation is needed.*

   Studies have demonstrated that indoor air impacts can be significantly variable with time across time frames of months, weeks, and sometimes even days and hours. Traditional methods of vapor intrusion pathway assessment are not well-suited for addressing this variability, as sampling at high frequencies and over very long periods of time would be required, and the decision-making would not be timely. Thus, there is a need for identifying new approaches that couple innovative short-term sampling, predictive tools, and data reduction guidance that are specifically designed with the temporal variability issue in mind.

   Furthermore, participants suggested that in order to improve health risk evaluations associated with vapor intrusion, environmental practitioners need to understand sampling protocols, with a specific focus on the spatial and temporal (short- and long-term) variability in VOC concentration in groundwater, well headspace, soil gas, sub-slab, ambient air, and indoor air samples.

2. *Demonstrations of protocols to streamline and improve vapor intrusion assessments, especially with respect to detecting the presence and impact of subsurface preferential VI migration pathways.*

The conventional generic conceptual model for vapor intrusion does not include preferential vapor migration pathways and there is little understanding of how these might affect vapor distributions and impacts, and the performance of mitigation efforts relative to the base case without preferential vapor migration pathways. The DoD would benefit from the development of conceptual models that cover the range of scenarios that might be encountered in both residential and commercial settings. Coupled with these would be tools to identify the presence and effects of subsurface preferential pathways on a site-specific basis.

2.2 Improved Site Characterization and Monitoring

While the development of methods for assessing and measuring vapor intrusion has been underway for several years, research and demonstration efforts on the underlying science governing the vapor intrusion pathway have been lacking. Tremendous uncertainty remains regarding how best to assess the vapor intrusion pathway. The monitoring required at sites where vapor intrusion is suspected can be expensive and time-consuming. It is also challenging to predict and measure the fate and transport of vapors in soil. The three high-priority needs identified under this topic are described below:

1. *Cost-effective characterization methods using real-time analytical tools that ensure confident vapor intrusion assessments.*

   On-site vapor intrusion analysis is an attractive characterization approach because additional locations can be added, either spatially or vertically, based on real-time data. It also allows early recognition of errors (e.g., leaked gas breakthroughs, inconsistent numbers, hardware blanks) on-site and collection of verification or replicate samples as needed.

   Although, laboratory-grade instruments, including mass spectrometers, can be used in the field to fulfill necessary analytical protocols, new cost-effective, real-time analytical tools are required to expedite vapor intrusion assessments and allow more accurate and timely mitigation decision-making. The DoD would benefit from demonstrations of standardized approaches to apply regulatory accepted laboratory-based technologies to real vapor intrusion sites to improve risk-based determinations.

~~2.~~ *Demonstrations of the use of vapor mass flux as a site characterization parameter that supports realistic determination of vapor intrusion impacts and design of subsequent cost-effective mitigation approaches.*

   Vapor intrusion assessments have generally focused on indoor air concentrations as the primary decision-making metric. We now know that indoor air concentrations can vary significantly on time frames of months, weeks, and sometimes days, and that relying on conventional indoor air monitoring can lead to inaccurate characterization of indoor air impacts. Thus there is interest in identifying other metrics that might be measured more confidently over shorter time frames and that can be used to estimate impacts. Vapor mass flux (or mass discharge) is one such quantity that has been suggested.

Evaluating vapor intrusion in terms of mass flux/mass discharge might also improve site conceptual models, be used to determine the effectiveness of mitigation systems, and indicate when mitigation systems can be shut down. In particular, it would be useful to have methods to measure mass flux that do not require building access.

3. *Tools to identify the presence and characteristics of subsurface preferential pathways that cause vapor intrusion processes and the performance of mitigation systems to behave differently than commonly conceptualized. Preferential pathways can result from sewer lines, soil macropores, foundation cracks, and shallow or perched water tables.*

   There are important differences between residential, commercial, and industrial buildings with respect to vapor intrusion. These differences can include building footprint size and volume, foundation type, floor slab construction, building height, number of floors, and air exchange from heating, cooling, and ventilation systems. In addition, present or former operations in commercial and industrial buildings may result in releases beneath the building, yielding sub-slab vapor concentrations not in proportion to what is found from dissolved phase VOC plumes.

   Guidance would be helpful to determine vapor intrusion mitigation systems either during construction or as a retrofit on a specific existing structure type. Strategies for mitigating vapor intrusion could include both active and passive techniques.

2.3 Improvements in Optimization and Sustainability

Although most DoD sites have or should soon have remedial action plans in progress, most will not achieve regulatory closure for many years. Some planned remedies will likely not perform as expected and will require modification or, in some cases, implementation of a different remedial action plan. In cases where vapor intrusion has been confirmed, tools are needed to periodically assess contaminant mitigation performance, identify and rectify problems, and optimize remediation operations and monitoring to minimize life cycle costs while meeting vapor intrusion remediation objectives. The two high-priority needs are identified in italics below:

1. *Demonstration of tools capable of providing life-cycle costs associated with vapor phase mitigation that addresses both pre-emptive and final mitigation systems.*

   Life-cycle assessment (LCA) is a compilation and evaluation of the inputs and outputs and the current or potential environmental impacts throughout a product's or project's life cycle (i.e., "cradle to grave"). In vapor intrusion scenarios, LCA can assist in identifying opportunities to improve the environmental performance at various points in the vapor intrusion project's life cycle, as well as in strategic planning, mitigation system design or redesign, and selection of relevant indicators of environmental performance, including measurement techniques.

   Tools and methods are needed that can periodically estimate the value of additional vapor intrusion characterization data in terms of life cycle cost savings, refine vapor intrusion model calibration taking into account new data from monitoring, assess the probability of

preemptive or current operations to meet vapor intrusion cleanup objectives, and reoptimize final mitigation system operation and monitoring variables to minimize expected life cycle cost based on performance and cost uncertainty.

2. *Improved and/or alternative tools to better evaluate and manage building pressure recycling (BPR) including temporal and spatial variability on vapor phase monitoring and mitigation.*

   Building pressurization is an option for vapor intrusion mitigation as models suggest that low levels of building pressurization might be sufficient to prevent vapor intrusion in some buildings. There is a need to better understand this technique and its applicability to different scenarios (e.g., industrial vs. residential buildings). Guidance is needed on designing and operating cost-efficient pressurization strategies, with recognition of differences between industrial and residential settings. It is not clear how much time is needed for pressurization for it to be fully effective or how much pressurization is needed for different buildings and specific environmental situations. Similarly, monitoring guidance is needed to ensure that pressurization effects are accurately measured and that monitoring plans are both efficient and protective of human health.

3.0 TECHNOLOGY TRANSFER NEEDS

One common theme that emerged from discussions of the four key technical areas (spatial and temporal variability, predictive modeling, characterization and long term monitoring, and mitigation system development) was an urgent need for SERDP and ESTCP to expand upon its existing technology transfer program. Participants consistently cited the need for targeted technology transfer efforts, and several felt the transfer of existing ESTCP products had not been sufficiently effective. Support for conferences and travel to training opportunities continues to decline, especially within the public sector, yet the need for targeted information increases. Remediation managers and their consultants need trustworthy, practical information that is easily accessible via the internet.

In particular, credible, well-advertised, and well-managed webinars are well-received, especially if they can be combined with continuing education credits needed by many professionals. Of particular value are archived webinars that can be accessed on-demand and optionally linked to continuing education credits. An overarching technology transfer need is therefore to continue and expand the current efforts to develop useful and web-based tools and training opportunities, and to make these resources as accessible as possible to managers, consultants, and regulators.

Technology transfer is needed that goes beyond generating documents. Specific suggestions resulting from the formal and informal workshop discussions amongst workshop participants are provided below.

- Videos that educate about vapor intrusion including RPMs and homeowners.
- Succinct computer-based information, i.e., Frequently Asked Questions (FAQs).
- Better coordination with the USEPA and the Interstate Technology Regulatory Council (ITRC) including improved means to document vapor intrusion results for regulatory guidance.
- Vapor intrusion website that includes articles and data results which would allow stakeholders and regulators to comment and provide feedback.
- Identify and attempt to build on existing vapor intrusion projects outside of the SERDP & ESTCP programs.
- Involvement at selected national conferences.
- Better use of internet-based tools (e.g., webinars, podcasts).

4.0 CONCLUSIONS

The workshop highlighted the progress that the DoD has made in addressing management of contaminant vapor intrusion. However, it was clear that many challenges in vapor intrusion assessments remain. Research and demonstrations have contributed to the past success, but specific areas still face challenges.

Discussions during the workshop focused on key technical areas: spatial and temporal variability, predictive modeling, characterization and long term monitoring, and mitigation system development. One common theme which emerged from discussions within the four technical areas was an urgent need for SERDP and ESTCP to expand upon its existing technology transfer program. Several recommendations were made for products that could be developed in the short term that would greatly benefit the end user community.

Research, demonstration, or technology transfer needs were identified during the workshop. Identification of these research and demonstration needs will directly impact the direction of SERDP and ESTCP investments over the next 3 to 5 years.

APPENDIX A: AGENDA

SERDP and ESTCP Vapor Intrusion Seminar & Workshop

Agenda

December 19, 2013 Arizona State University, Tempe AZ		
0900	**Welcome and Introduction** **SERDP & ESTCP Vapor Intrusion Overview**	Andrea Leeson SERDP and ESTCP
0930	Overview of SERDP Project ER-1686: Integrated Field-Scale, Lab-Scale, & Modeling Studies for Improving Ability to Assess Groundwater to Indoor Air Pathway at Chlorinated Solvent-Impacted Groundwater Sites	Paul Johnson Arizona State University
0950	Overview of ESTCP Project ER-200830: Development of More Cost-Effective Methods for Long-Term Monitoring of Soil Vapor Intrusion to Indoor Air Using Quantitative Passive Diffusive-Adsorptive Sampling Techniques	Todd McAlary Geosyntec
1010	Overview of ESTCP Projects ER-201025 and ER-201119: Distinguishing Between Vapor Intrusion and Indoor Sources of VOCs	Tom McHugh
1025	Overview of ESTCP Project ER-201322: Demonstration/Validation of More Cost-Effective Methods for Mitigating Radon and VOC Subsurface Vapor Intrusion to Indoor Air	Todd McAlary Geosyntec
1045	**Morning Break**	
1100	"Customer" presentations of needs (5 min each) • Kyle Gorder/Eric Dettenmaier (Hill AFB) • Tanwir Chaudhry (U.S. Navy) • John Boyer (State of New Jersey) • Helen Dawson (former USEPA) • Lenny Siegel (CPEO)	
1130	Brainstorming	
1215	**Lunch**	
1300	Brainstorming	
1345	Breakout Sessions: Identification of Data Gaps in the Assessment of Vapor Intrusion	Workshop Participants
1045	**Morning Break**	
1515	Breakout Session Results and Discussion	Workshop Participants
1630	**Adjourn**	

APPENDIX B: ATTENDEE LIST

Attendee List

John Boyer
New Jersey Department of Environmental Protection

Dan Carr
Sanborn, Head & Associates, Inc.

Tanwir Chaudhry
Naval Facilities Engineering and Expeditionary Warfare Center

Helen Dawson
Geosyntec Consultants

Erik Dettenmaier, Ph.D.
Hill AFB Environmental Restoration

Kyle Gorder
Hill AFB Environmental Restoration

Yuanming Guo
Arizona State University

Ian Hers, Ph.D.
Golder Associates Ltd.

Chase Holton
Arizona State University

Paul Johnson, Ph.D.
Arizona State University

Jill Johnston, Ph.D.
University of North Carolina

Carmen Lebrón
Naval Facilities Engineering and Expeditionary Warfare Center

Andrea Leeson, Ph.D.
SERDP and ESTCP

Alana Lee
U.S. Environmental Protection Agency

Loren Lund, Ph.D.
CH2M HILL

Jackie MacDonald Gibson, Ph.D.
The University of North Carolina at Chapel Hill

Todd McAlary
Geosyntec Consultants

Tom McHugh, Ph.D
GSI Environmental Inc

Kelly Pennell, Ph.D.
University of Kentucky

Deanne Rider
HGL

Lenny Siegel
Center for Public Environmental Oversight

Hans Stroo, Ph.D.
Stroo Consulting, LLC

Eric Suuberg, Ph.D.
Brown University

Marvin Unger, Ph.D.
HGL