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May 17, 2019 **VIA PRIVATE CARRIER**

Mr. James R. Carroll
Program Administrator
Land Restoration Program
Land Management Administration
Maryland Department of the Environment
1800 Washington Boulevard, Suite 625
Baltimore, Maryland 21230

Subject: Transmittal of the 2019 Vapor Intrusion Management Plan
Lockheed Martin Corporation – Middle River Complex
2323 Eastern Boulevard, Middle River, Baltimore County, Maryland

Dear Mr. Carroll:

For your review please find enclosed two hard copies with a CD of the above-referenced document. This document was developed as an update to the previous Vapor Intrusion Management Plan(s). If possible, we respectfully request to receive MDE's document review comments by July 9, 2019. Once approved, this plan will replace and supersede earlier versions of the Vapor Intrusion Management Plan.

Please let me know if you have any questions. My office phone is (301) 548-2209.

Sincerely,

Thomas D. Blackman
Project Lead, Environmental Remediation

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2019 VAPOR INTRUSION MANAGEMENT PLAN
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
2323 EASTERN BOULEVARD
MIDDLE RIVER, MARYLAND

Prepared for:
Lockheed Martin Corporation

Prepared by:
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May 2019

Revision: ______

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ACRONYMS

$\mu g/m^3$	microgram(s) per cubic meter
AF	attenuation factor
atm-m^3/mol	atmosphere cubic-meter(s) per mole
ca	carcinogenic
COC	chemical(s) of concern
EESH	Energy, Environment, Safety, and Health (the Lockheed Martin Corporation group responsible for environmental programs at the Middle River Complex)
FID	flame-ionization detector
GAC	granular activated-carbon
HQ	hazard quotient
HI	hazard index
HVAC	heating, ventilation, and air conditioning
IA	indoor air
ILCR	incremental lifetime-cancer-risk
IRIS	Integrated Risk Information System
LMCPI	LMC Properties, Inc.
Lockheed Martin	Lockheed Martin Corporation
MDE	Maryland Department of the Environment
$\mu g/m^3$	micrograms per cubic meter air
mm Hg	millimeter(s) of mercury
MRC	Middle River Complex
nc	noncarcinogenic
OSHA	Occupational Safety and Health Administration
PCE	tetrachloroethene (formerly known as perchloroethylene)
PID	photoionization detector

ppm	part(s) per million
PPRTV	provisional peer-reviewed toxicity value
PPZ	potassium permanganate zeolite
RSL	regional screening level
SSD	sub-slab depressurization
SSDS	sub-slab depressurization system
STEL	short-term exposure limit
SV	sub-slab vapor
Tetra Tech	Tetra Tech, Inc.
TCE	trichloroethene
TWA	time-weighted average
USEPA	United States Environmental Protection Agency
VI	vapor intrusion
VOC	volatile organic compound

SECTION 1
INTRODUCTION

Vapor intrusion (VI) is the migration of volatile chemicals from the subsurface into the indoor air (IA) of buildings above. This document was developed as a resource for personnel at the Lockheed Martin Corporation (Lockheed Martin) Middle River Complex (MRC) to help manage known vapor intrusion pathways, and/or investigate yet unknown vapor intrusion pathways at the site that may adversely affect facility indoor air. Vapor intrusion should be evaluated as a potential human-exposure pathway whenever volatile chemicals are in underlying soil, soil gas, or groundwater near existing structures and/or buildings planned for construction. The following sections will introduce vapor intrusion concepts and briefly summarize vapor intrusion issues at the Middle River Complex.

1.1 VAPOR INTRUSION CONCEPTS

Volatile chemicals can readily evaporate under typical environmental conditions. This volatility can result in their migration from contaminated groundwater or soil through unsaturated soil into the indoor air of buildings near zones of subsurface contamination. The United States Environmental Protection Agency (USEPA) defines a chemical as volatile if its vapor pressure is greater than one millimeter of mercury (mm Hg), or if its Henry's Law constant is 1×10^{-5} atmosphere cubic-meters per mole (atm-m^3/mol) or greater (USEPA, 2015a). Henry's Law constants characterize the equilibrium partitioning of a dissolved volatile chemical between the liquid phase and the gas phase above the liquid.

Volatile organic compounds (VOCs) are the class of chemicals with the greatest interest for this subsurface-to-indoor-air pathway, and include common chemicals such as benzene (e.g., from light petroleum products such as gasoline) and chlorinated solvents (e.g., trichloroethene [TCE]). The United States Environmental Protection Agency has identified more than 100 chemicals with sufficient volatility and toxicity to pose a potential vapor intrusion hazard (USEPA, 2015b). These chemicals should be included in any vapor intrusion investigation or program if they are known or reasonably assumed to have been used or released at a site. Typically, the potential for vapor intrusion is evaluated during a site investigation.

Potentially applicable responses to vapor intrusion into existing buildings include passive or active ventilation systems, floor sealants, etc. The potential for vapor intrusion in future structures should be addressed during design; any necessary measures to reduce vapor intrusion, including those associated with construction, should be included in the design. A typical approach for assessing risks posed by a possible vapor intrusion pathway, including its mitigation and remediation, is summarized below:

Evaluate whether exposure to vapors poses an acute (immediate) risk to building occupants: This can include both acute health risks and, in extreme cases, the risk of combustion or explosion. For acute risks, field instruments will be used, and results will be compared to federal Occupational Safety and Health Administration (OSHA) short-term and ceiling exposure levels (see Section 3.1 for a description of steps to manage acute risks). Although these levels are used to regulate worker exposure to chemicals in use at a facility, they can also be used to estimate potential acute health risks. If acute risks from vapor intrusion are identified, the affected area will be evacuated until the risks have been mitigated. If no acute risks are identified, a screening-level vapor intrusion evaluation may be conducted. The threat of an acute risk due to vapor intrusion at the Middle River Complex is unlikely, based on historical contamination and the high degree of investigation and remediation completed to date. Concentrations of trichloroethene in indoor air over the course of the investigation have exceeded screening levels (See Section 2.2.1) but have never exceeded OSHA short-term and ceiling exposure levels.

Conduct a screening-level assessment of site contaminants: This evaluation typically involves comparing site soil gas or groundwater data to conservative (i.e., highly protective of human health) risk-based screening values. This evaluation applies when contamination in site environmental media is attributable to site operations and may pose a risk to human health. If site environmental media concentrations are less than screening levels, a low potential for vapor intrusion risk exists, and further action is likely unnecessary. If contaminant concentrations in one or more affected environmental media exceed risk-based screening values, then an indoor air investigation might be necessary.

Conduct a site-specific vapor intrusion pathway evaluation: Site-specific data, including sub-slab soil vapor and/or indoor air samples, can be collected. Multiple lines of evidence can be used to evaluate the magnitude and extent of vapor intrusion. This evaluation also involves comparing site data to site-specific trigger levels. For indoor air, the trigger level is equal to the screening level; trigger levels for sub-slab vapor (SV) are based on a multiple of the indoor air trigger-level (see Section 2.2.2). If site concentrations are greater than site-specific trigger levels, further action (i.e. mitigation) may be warranted.

Evaluate mitigation/remediation options, if necessary: Mitigation involves techniques that prevent (or minimize) vapors associated with subsurface contamination from entering and accumulating in a building's indoor air. Common mitigation measures include installation of a passive venting system; installation of sub-slab depressurization or pressurization devices; sealing cracks, sumps, and other possible preferential pathways; and installing vapor proof membranes. At active facilities, adjusting the heating, ventilation, and air conditioning (HVAC) system may be an option, as well as instituting exposure controls for land or building use.

Remediation treats and removes (or isolates) chemicals from contaminated subsurface media. Effective remediation can eliminate or greatly reduce the threat of vapor intrusion. Common remediation options include soil removal, soil-gas extraction, and groundwater treatment. Mitigation and remediation can be performed concurrently or separately, depending on site-specific characteristics and access constraints.

1.2 VAPOR INTRUSION AT THE MIDDLE RIVER COMPLEX

The Middle River Complex land parcels owned by LMC Properties, Inc., (LMCPI) have been subject to extensive, and, in some cases, ongoing site characterization studies to support remediation decisions. Ongoing environmental characterization of the Middle River Complex has identified volatile organic compound contamination in subsurface soil and groundwater under or near occupied workspaces. Other non-subsurface sources could also possibly affect indoor-air contaminant concentrations, including indoor emissions from process chemicals, building materials, and other sources, and from ambient (outdoor) air contributions.

The site-specific vapor intrusion risk assessment prepared in 2006 for the Middle River Complex was based on modeled indoor air concentrations from sub-slab vapor concentrations in samples collected from beneath the Building A basement and former first-floor plating shop (currently the newly expanded bond layup room), and from samples collected beneath the southern section of the Building C basement. The 2006 risk assessment indicated that health risks were at or below Maryland Department of the Environment and United States Environmental Protection Agency risk threshold values (Tetra Tech, 2006). Comparison of sub-slab vapor concentrations to applicable screening levels indicated that risks associated with vapor intrusion could potentially be unacceptable to onsite workers (see Section 2.2.1). Uncertainties inherent in modeling led to a supplemental investigation to determine whether volatile organics were in indoor air and whether these indoor air concentrations could be associated with subsurface contamination.

Indoor air monitoring in Middle River Complex Buildings A, B, and C has been ongoing since 2006. During the first three rounds of sampling (February and December 2006, and April 2007), trichloroethene was detected in indoor air and sub-slab vapor. Trichloroethene concentrations ranged between 0.22 and 36 micrograms per cubic meter air (µg/m^3) in indoor air and between 60.4 and 6,200,000 µg/m^3 in sub-slab vapor. An exceedance of the trichloroethene screening level (18 µg/m^3) was detected at one indoor air sampling location. The trichloroethene screening level in 2006 (18 µg/m^3) has since been reduced to 8.8 µg/m^3. Trichloroethene in indoor air samples in Building A may have been associated with sub-slab vapor migration at the former plating shop and a volatile organic chemical groundwater plume that lies beneath the building. Trichloroethene in indoor air samples in Building C basement may have been associated with the machine shop.

A marker chemical, *cis*-1,2-dichloroethene, was also detected at concentrations ranging between 0.3 µg/m^3 and 3.8 µg/m^3 in indoor air and between 22 µg/m^3 and 1,550,000 µg/m^3 in sub-slab vapor. *cis*-1,2-Dichloroethene is considered an indicator of possible vapor intrusion, because it is not a manufactured chemical and is only found when other chlorinated compounds (such as trichloroethene) break down. The indoor air concentrations of *cis*-1,2-dichloroethene were less than its screening level at that time (260 µg/m^3), but its soil vapor concentrations exceeded its former screening level (8,700 μg/m^3); since then, the United States Environmental Protection Agency has withdrawn the toxicity factors for *cis*- and *trans*-dichloroethene, and no currently applicable screenings levels are available for these compounds.

Results from the first three monitoring rounds led the project team to recommend mitigation for locations where chemicals in sub-slab vapor were detected at concentrations above risk-based screening levels. In response, two sub-slab vapor mitigation systems were designed and installed: one beneath the Building A former plating shop, and one beneath the southern end of the Building C basement, with full system startup on March 31, 2008. The project team also recommended additional indoor air and sub-slab vapor sampling to address the analytical variability identified during subsequent rounds of monitoring.

To date, appropriate response actions have been implemented at the site to mitigate these potential health risks. Among these actions were the installation of sub-slab depressurization systems (SSDS) in areas of Buildings A and C with elevated sub-slab vapor concentrations, and periodic sub-slab and indoor-air monitoring rounds. The sub-slab depressurization systems extract vapor from the sub-slab area, reducing the pressure driving vapors into indoor spaces. The recovered vapor is treated, and the clean air is discharged to the atmosphere. Although some vapors are recovered and treated, the purpose of these systems is not source recovery, but rather mitigation of vapor intrusion.

Analytical results for Buildings A, B, and C indicated that a subset of the chemicals of concern (COC) identified in the subsurface have also been detected in background and/or indoor air samples. Specifically, benzene, ethylbenzene, xylenes, 1,1-dichloroethane, 1,2-dichloroethane, trichloroethene, vinyl chloride, and naphthalene have been detected in sub-slab vapor at concentrations greater than screening levels, and have also been detected in background (outdoor) and/or indoor air samples. Background samples collected at the four corners of the facility property have been used to evaluate the potential for indoor air concentrations of chemicals possibly attributable to non-facility ambient sources; these samples have also been used to identify possible chemical contributions from current site operations. Indoor air concentrations for chemicals of concern were compared to risk-based screening levels derived using conservative default United States Environmental Protection Agency toxicity values and default inhalation-exposure assumptions for industrial workers. These analyses indicate that most volatile organic compounds detected in indoor air samples are probably *not* associated with sub-slab-vapor intrusion, because they were detected either at concentrations less than screening levels or not at all in sub-slab vapor.

After the initial installation of the sub-slab vapor mitigation systems in Building A, three additional upgrades were installed.

- In October 2010, the sub-slab depressurization system in Building A was expanded to address elevated concentrations of sub-slab volatile organic compounds detected beneath the middle area of the Building A basement. During this first-phase expansion, two horizontal vapor-extraction trenches were installed, and the two existing 200-pound granular activated-carbon (GAC) drums that removed volatiles from system exhaust gases were replaced with two 400-pound drums.

- In January 2015, three stand-alone indoor-air filters were installed in the southeastern corner of the Building A basement. These filters operate continuously to address intermittent trichloroethene concentrations above the indoor-air screening level.

- A second-phase system expansion was installed in Building A in February 2016 to address areas along the building's eastern side, where elevated concentrations of volatile organic compounds were detected in the sub-slab in 2014 and 2015. The system now includes two parallel trains of two 400-pound granular activated-carbon drums. The additional drums were added to reduce the number of changeouts needed for the expanded system and to relieve back-pressure that may have led to blower failure issues after the second-phase expansion.

- In May 2017, three additional air-purifying filters were installed in the Building A basement as an interim measure to target floor features (e.g., drains and sumps) that had shown elevated trichloroethene concentrations. A continuous air-monitoring survey identified significant sources of indoor air contamination in the basement at sumps associated with former heater rooms. In the summer of 2017, a closed-circuit television (CCTV) camera survey of floor features conducted in Building A basement determined that the underground network of floor drains, pipes, and manholes/sumps are interconnected in some circumstances.

- As part of the 2017 third-phase expansion, one vertical vapor extraction point and one vapor monitoring point (VMP) were installed in June 2017, a second moisture separator was added to the system's equipment skid, and the system's extraction piping was extended in the basement to extract vapor from sump HRS-5 and other to-be-determined sumps or extraction points.

Following the startup of the sub-slab depressurization system in the southern end of the Building C basement, subsequent monitoring of the Building C basement identified an area beneath the east-central part of the basement with sub-slab-vapor contamination. This contamination is believed to be associated with the former Patriot missile canister plating, painting, and manufacturing operation. With the identification of this contamination, the sub-slab depressurization system in Building C was expanded.

- The first-phase expansion of the sub-slab depressurization system was completed in October 2012 to address the middle area of the Building C basement and to continue to address the southern portion of the basement. The first-phase expansion installed four additional vapor extraction wells, replaced the granular activated-carbon drums with larger vessels (and updated associated piping, fittings, and appurtenances) for removal of trichloroethene and other volatile organic vapor, and installed one potassium permanganate zeolite (PPZ) drum for removal of vinyl chloride vapor.

- The second-phase system expansion, completed in May 2013, more thoroughly addressed sampling results obtained over time from the middle area of Building C basement. Five additional vapor extraction wells were installed, the system equipment skid was replaced and relocated, a heat exchanger and post-heat-exchanger moisture separator was added, a mist-eliminator pad was installed in the exhaust stack, and the vapor treatment drums were relocated to the approved indoor location.

Periodic combined rounds of indoor air and sub-slab vapor monitoring continue to investigate possible sources of sub-slab vapor, evaluate the performance of the sub-slab depressurization systems, and provide ongoing protection of worker health and safety with respect to possible vapor intrusion. The current monitoring program includes sampling twice annually, targeting both winter (February) and summer (August) conditions.

SECTION 2
SCREENING LEVELS, TRIGGER LEVELS, AND CORRESPONDING ACTIONS

Vapor intrusion (VI) into building interiors increases the possibility that individuals could be exposed to sub-slab chemicals and the possible adverse health effects associated with exposure to these chemicals. Screening levels and trigger levels are risk-based concentrations that are considered protective of human health assuming exposure only through the inhalation pathway. These levels are derived using United States Environmental Protection Agency's (USEPA's) risk assessment methodology.

2.1 BACKGROUND

Screening levels used to evaluate inhalation exposure include USEPA regional screening levels (RSLs) (USEPA, 2018). RSLs are risk-based concentrations derived from standardized equations that combine exposure assumptions with USEPA toxicity data.

Screening levels for noncarcinogenic health effects are protective for chronic exposures of long durations, such as working at a facility (i.e., 25 years). Screening levels for carcinogenic health effects are considered protective over a lifetime (i.e., 70 years) while working over a 25-year period. Screening levels are generic (i.e., they are calculated without site-specific information), and are typically very conservative. Both the USEPA and the Maryland Department of the Environment (MDE) recognize that chemical concentrations above published risk-based screening levels do not necessarily identify a hazardous situation or trigger a response action. However, exceeding a screening level does suggest that further evaluation of possible risk posed by site contaminants is appropriate.

Trigger levels are site-specific, risk-based concentrations that indicate the need for specific actions. Trigger levels are used to assess VI at the Middle River Complex (MRC) and evaluate when mitigation might be needed or can be discontinued. Trigger levels are intended to be used as a guide to determine:

- whether additional indoor air (IA) and sub-slab vapor (SV) monitoring are needed
- whether mitigation is required
- whether/when an emergency response is indicated

2.2 DEVELOPMENT OF VI SCREENING LEVELS AND TRIGGER LEVELS

2.2.1 Indoor Air Screening-Level Calculations

The default IA screening levels for industrial exposure set forth in the *USEPA Regional Screening Levels for Chemical Contaminants at Superfund Sites* (USEPA, 2018) are currently used to evaluate the contaminants detected in the semiannual SV and IA sampling events at the MRC. The USEPA industrial IA RSLs are shown on Table 2-1. USEPA generates both carcinogenic (*ca*) and noncarcinogenic (*nc*) RSLs. For some chemicals, only one type of screening level is available.

USEPA carcinogenic RSLs correspond to a cancer-risk level of 1×10^{-6} (i.e., a one in a million probability), whereas noncarcinogenic RSLs correspond to a hazard quotient (HQ) of 1 (corresponding to a concentration above a threshold dose that causes an adverse health effect). Although USEPA screening levels are calculated using a carcinogenic-risk level of 1×10^{-6}, the target carcinogenic-risk level for the MRC is 1×10^{-5} (a one in 100,000 probability), in accordance with MDE requirements. Thus, the site-specific IA screening level is either 10 times the USEPA carcinogenic RSL (which corresponds to a carcinogenic risk level of 1×10^{-5}), or the noncarcinogenic RSL, whichever value is lower.

Concentrations of chemicals detected in SV are compared to their respective screening levels, which are derived in accordance with the methods discussed in Appendix A of the USEPA *OSWER Technical Guide for Assessing and Mitigating the Vapor Intrusion Pathway from Subsurface Vapor Sources to Indoor Air* (USEPA, 2015a). SV screening levels are derived by applying an attenuation factor (AF) of 0.03 to IA screening levels. The AF is an estimate of the amount by which subsurface-vapor concentrations migrating into IA spaces are assumed to be reduced due to diffusive, advective, and/or other attenuating mechanisms. Simply stated, SV is expected to undergo dilution and dispersion upon migration into IA; the AF is the ratio of the IA concentration of a constituent to its SV concentration, under a conservative VI scenario (i.e., where other common sources of attenuation are absent, for example, where there is no increased ventilation due to open bay doors). The SV screening level is derived by dividing the IA screening level by the AF. USEPA derived this AF (0.03) based on information in its vapor intrusion database (USEPA, 2012a); this database also details the calculations used to determine AFs. USEPA has collected VI data (primarily from residential sites) to improve knowledge and understanding of VI, and of attenuation of vapors between the subsurface and IA.

Screening levels for some analytes have changed since the inception of the MRC monitoring program. Updated screening levels are listed below; these screening levels reflect recent USEPA review and incorporate the most recent toxicity data for these compounds.

- ***Trichloroethene:*** From 2009 until August 2011, trichloroethene (TCE) sampling data were compared against an IA screening level of 25 micrograms per cubic meter (µg/m^3), which was the MDE screening level for TCE in industrial air. However, on September 28, 2011, USEPA updated its toxicological review for TCE (USEPA, 2011b) and subsequently published new toxicity criteria on USEPA's Integrated Risk Information System (IRIS) database, resulting in a new TCE screening value (8.8 µg/m^3) for industrial air. This value is the lower of the carcinogenic and noncarcinogenic values for TCE, and is based on noncarcinogenic effects. Specifically, this value was developed to protect a developing fetus. Accordingly, any TCE exceedance of the IA screening level should be addressed quickly, as discussed in Sections 2.2.3 and 3.1. This lower screening value (8.8 µg/m^3) was adopted by MDE, and is now used to screen the IA results.

- ***Methylene chloride****:* In November 2011, USEPA also updated its toxicological review for methylene chloride (USEPA, 2011a), and new toxicity criteria were published on IRIS. A new screening value of 2,600 µg/m^3 was established for methylene chloride in industrial air. This is the lower of the carcinogenic/noncarcinogenic values for methylene chloride, and is based on noncarcinogenic effects. This value is used to screen the IA results in anticipation of MDE adopting the updated USEPA guidance. The previous screening value was 261 µg/m^3.

- ***Tetrachloroethene****:* USEPA updated its toxicological review for tetrachloroethene (PCE; formerly known as perchloroethylene) in February 2012 (USEPA, 2012b), and published new toxicity criteria on IRIS. The new criteria established a PCE screening value of

180 µg/m^3 in industrial air (USEPA, 2012b). This is the lower of the carcinogenic/noncarcinogenic values for PCE, and is based on noncarcinogenic effects. This value is used to screen the IA results in anticipation of MDE adopting the updated USEPA guidance. The previous screening value was 20.8 µg/m^3.

- ***Xylenes:*** USEPA updated its RSLs for xylenes in May 2011. Previously, the RSLs for the individual isomers of xylene (3,070 µg/m^3) had been based on the California Environmental Protection Agency reference doses, and the industrial RSL for total xylenes (440 µg/m^3) was based on USEPA's reference dose. In May 2011, USEPA revised its RSL for xylene isomers, and they are now based on the USEPA reference dose.

- **trans-*1,2-Dichloroethene**:* USEPA removed its RSL for *trans*-1,2-dichloroethene in June 2014. Until June 2014, its RSL (260 µg/m^3) was a provisional peer-reviewed toxicity value (PPRTV). USEPA's review in 2010 found that the studies reviewed for the PPRTV value were insufficient to support derivation of a reference concentration. Current practice by the PPRTV program states that once an IRIS assessment becomes available for any given chemical, the PPRTV assessment is removed from the PPRTV electronic library. Hence, the RSL for *trans*-1,2-dichloroethene was removed. Since the screening level for ***cis*-1,2-dichloroethene** was based on the value for *trans*-1,2-dichloroethene; its screening level was also removed. Consequently, no current screening levels for *cis*- or *trans*-1,2-dichloroethene are available (USEPA 2014).

TCE has periodically been detected in IA in the Building A basement at concentrations greater than the IA screening level (8.8 µg/m^3). However, employees are not typically working in the basement. Access to the basement is controlled by management to limit access to the basement. Therefore, to address the limited presence of workers in the basement, a basement-specific screening level for TCE (35 µg/m^3) was derived. This value was approved by MDE in 2017 (Lockheed Martin, 2017). TCE concentrations in IA samples collected in Building A basement are compared to this basement-specific screening level for decision-making purposes.

2.2.2 Indoor Air Trigger-Level Calculations

The intent of establishing IA trigger levels is to identify contaminant concentrations in IA that are still sufficiently low enough that decisions regarding possible intervention can be made. The project team agreed that modifying IA screening levels to establish IA trigger levels would result in trigger levels so low that background concentrations might result in unnecessary action being taken, or so high that they would not be conservative/protective of human health. To ensure protection of human health, the project team agreed that the industrial risk-based IA screening levels should be used as the IA trigger levels (see Table 2-2).

2.2.3 Sub-Slab Vapor Trigger-Level Calculations

The intent of establishing the SV trigger levels is to identify SV contaminant concentrations that are sufficiently low to enable decisions regarding possible intervention. The SV trigger levels are equal to MDE "Target Soil-Gas Tier 1" values (MDE, 2012). These values are equal to 100 times the IA trigger level.

Historical data indicate that building slabs at the MRC have been relatively effective in controlling or even preventing SV migration. Elevated SV concentrations of volatile organic compounds (VOCs) have been detected beneath Buildings A and C; however, SV contaminants observed in IA have rarely been detected at concentrations above IA screening levels. As such, the use of SV trigger values (Table 2-2) that are 100 times higher than the indoor air trigger value is considered appropriate, given historical site-specific results.

VOC (mainly TCE) concentrations in SV are above trigger levels in certain areas. These areas are defined by multiple SV samples and are located where sub-slab depressurization system (SSDS) operation is underway. Monitoring and analysis will continue across the Block I buildings (i.e., Buildings A and C), and additional mitigation will be proposed in the future if deemed necessary.

2.2.4 Application of Trigger Levels

As previously discussed, trigger levels give site managers a tool with which to evaluate possible VI risk before either SV or IA contaminant concentrations reach a level of concern. Figure 2-1 is a decision matrix for using these trigger levels. When SV and/or IA concentrations exceed the trigger levels, or when cumulative carcinogenic or cumulative noncarcinogenic risks (explained below) exceed target levels, steps should be taken to further evaluate whether a complete VI pathway exists. If a pathway exists, then steps may be implemented, as appropriate, to reduce employee exposures.

Risk Characterization

The decision matrix in Figure 2-1 uses USEPA risk-based ranges to address hypothetical scenarios associated with contamination in SV and IA. USEPA characterizes possible risk (i.e., the probability of a harmful effect) from chemical exposure as carcinogenic, noncarcinogenic, or both. USEPA describes the excess cancer-risk by using the incremental lifetime-cancer-risk (ILCR) associated with the chemical. The ILCR represents the probability of an exposed individual to develop cancer (due to that exposure) by age 70. USEPA generally considers excess cancer risks below one chance in a million (i.e., 1×10^{-6}) to be so small as to be negligible, and risks above one in 10,000 (i.e., 1×10^{-4}) sufficiently large that some sort of remediation may be needed.

For most chemicals, noncarcinogenic risk is expressed as a ratio between a chemical's dose and its chemical-specific toxicity value; this ratio is the noncancer HQ. If the HQ for a chemical is less than or equal to 1, USEPA considers that chemical to have no appreciable noncarcinogenic risks (noncancer health effects). If the HQ exceeds 1, noncancer effects may, but not definitely, occur, as the margin of safety inherent in the derivation of the toxicity values makes these values conservative. The larger the HQ value, the more likely that an adverse effect could occur.

As shown on Figure 2-1, responses and activities are correlated to the degree of possible risk, ranging from no action at levels of low or no risk, to monitoring when risks fall within the USEPA risk range, to intervention when risks exceed the upper bounds of the risk range defined by USEPA. In some cases, all contaminant concentrations may be less than their respective screening levels, but the cumulative risks might be greater than target risk levels. Cumulative risk is the sum of the carcinogenic or noncarcinogenic risks of the detected contaminants. For cases when the cumulative noncarcinogenic hazard index (HI) is greater than 1, then the hazard index will be evaluated on a target organ basis.

Trigger-Level Decision Matrix

TCE has been periodically detected in Building A IA at concentrations greater than its established screening levels. Subsequent to each future round of sampling, Tetra Tech will resample any IA location with a TCE concentration exceeding its trigger level (8.8 µg/m^3 on the first floor, or 35 µg/m^3 in the basement [see below]) to confirm the exceedance. Resampling will be conducted within approximately five days of receipt of the preliminary data package (before data validation is completed) to determine whether the exceedance can be reproduced under the same or similar conditions. A letter report will then be prepared detailing the results.

If TCE concentrations in the IA resample are greater than trigger levels (regular or basement-specific), or if the cumulative IA risk of all detected contaminants is greater than the 1×10^{-5} risk level or an HI of 1, then the results will be communicated, and monitoring should continue. If the cumulative IA risk is greater than the 1×10^{-4} risk level or an HI of 3, then exposure to contaminants will be mitigated, as discussed in Section 3.

If TCE concentrations in the IA resample are less than trigger levels (regular or basement-specific), or if the cumulative IA risk of all detected contaminants is less than the 1×10^{-5} risk level or an HI of 1, SV concentrations will be evaluated. If SV concentrations are greater than screening levels, then the results will be communicated, and monitoring will continue. If the SV concentrations are greater than trigger levels, then exposure to contaminants will be mitigated as discussed in Section 3; results will be communicated, and monitoring will continue.

For exceedances of compounds other than TCE, other information, such as historical data and the possibility of that chemical’s use in the workplace, will be used to determine if immediate resampling is necessary.

Evaluate Potential Indoor Air Sources and Preferential Pathways

The sampling team may also explore the area with the exceedance visually and with a portable field instrument to determine if any IA sources or preferential pathways could have contributed to the exceedances(s). This supplemental information will support the multiple lines of evidence used to make decisions regarding any actions.

Reporting of Results and Decision Matrix Evaluation

Lockheed Martin Corporation (Lockheed Martin) will receive the most recent data from the semiannual SV and IA sampling episodes, SSDS monitoring, and any other SV or IA sampling at the MRC, with comparisons to the trigger and screening levels included, so that areas of concern can be identified and actions taken as necessary. When SV and IA concentrations fall below the trigger levels, decisions regarding stopping the SSDS or modifying active and passive mitigation methods can be made. Cessation may be warranted, because, as stated earlier, trigger levels incorporate conservative safety factors.

2.3 SSD SYSTEM SHUTDOWN

Once an SSDS has reduced SV contaminant concentrations below the previously discussed SV trigger levels, Lockheed Martin can evaluate SSDS shutdown. To be eligible for shutdown, a system should demonstrate consistent reduction of SV and IA contaminant concentrations within its radius of influence. SV contaminant concentrations must remain below the trigger levels for at least one year (or for two consecutive semiannual sampling rounds) before system shutdown can be considered. After system shutdown, rebound testing will check SV concentrations and compare them to historical elevated SV concentrations and to trigger levels equal to MDE “Commercial Tier 1 Soil Vapor” screening levels (MDE, 2012). A rebound-testing plan will be submitted to Lockheed Martin and the Remedial Technical Operation before system shutdown. Figure 2-2 shows the decision logic illustrating when an SSDS shutdown can occur.

VOC concentrations measured in SV while the mitigation system is operating would most likely not be indicative of SV concentrations once the system has been turned off. To evaluate the reduction of SV contamination during SSDS operation, semiannual SV and IA data will be compared to the SSDS influent concentrations. This evaluation, however, is done without knowing the remaining source(s) mass or the extent of source depletion. This is why presence or absence of rebound is difficult to predict.

System-influent measurements provide a spatially averaged SV contaminant concentration (because the vapor is being drawn from all extraction points). This averaged concentration is less likely to be biased by a single sample with a highly elevated or highly depressed result. Once the results of the SSDS-influent monitoring and SV/IA monitoring meet the trigger levels previously described, the system can be shut down to undergo rebound testing. Source reduction is a side effect of SSDS mitigation, so rebound where a sub-slab source is present can be expected. Shutdown and rebound testing parts of the SSDS extraction network can be considered where rebound test results have satisfied criteria in individual SSDS subsections.

To perform a rebound test, the SSDS must be shut off for several weeks or months, depending on site conditions. Previous incidences of SSDS shutdown have indicated that rebound can occur within two weeks. The rebound test will determine whether SV and IA contaminant concentrations increase (i.e., rebound) after the system has been turned off. The actual length of time the system remains dormant will depend on site-specific conditions that might reduce vapor flow.

At the beginning of the test, SV samples are collected from the system influent (while the system is operating) and from the permanent vapor monitoring points within the system radius of influence (at least 24 hours after the system has been turned off). These samples document baseline conditions. During the shutdown test period, IA and SV samples are collected monthly from the same locations for at least six months. If contaminant concentrations in SV and IA have not increased during the shutdown period and remain below trigger levels, then the decision may be made to remove the system. Beginning approximately two weeks after shutdown, system influent and select monitoring and extraction points will be sampled monthly to determine the degree of rebound (if any). If contaminant concentrations remain below trigger levels after six months of monitoring, we recommend reverting to the semiannual monitoring program, and keeping the SSDS dormant.

If SV contaminant concentrations show a clearly increasing trend from baseline conditions, but are still below trigger levels, then rebound testing should continue, as contaminant concentrations may continue to increase, or have been merely fluctuating over time. If contaminant concentrations in SV and/or IA have increased and are above trigger levels, rebound has occurred, and the system will need to be reactivated. In that case, monitoring should continue, and rebound testing should be repeated after SV and/or IA monitoring results have produced concentrations below the trigger levels for at least three consecutive semiannual sampling rounds. The date of new rebound testing will be determined based on site-specific SV concentrations and trends.

SECTION 3
MANAGEMENT OF POSSIBLE VAPOR INTRUSION RISKS

If calculated health risks associated with exposure via vapor intrusion (VI) from chemicals of concern (COC) exceed target risk levels, that risk must be appropriately managed. Early planning will assist site management to make informed decisions. To manage possible VI risk, the results of indoor air (IA) and sub-slab vapor (SV) investigations are integrated with other considerations to identify the need for mitigation, remedial action, or other risk-reduction activities. Additional factors, such as regulatory requirements, technical implementability, potential liability, and employee/tenant acceptance must also be considered when making risk management decisions.

This section addresses management of acute and chronic risks associated with exposure to volatile organic compounds (VOCs) due to vapor intrusion. The section also addresses increased soil vapor concentrations resulting from sub-slab depressurization system (SSDS)shutdowns due to power failures or mechanical problems. Events triggering the communication of risks and investigation results to building occupants, management, and regulatory agencies are also discussed. Finally, this section provides exit strategies for SSDS shutdown or for terminating the VI monitoring program.

As discussed in this section,

- *Remediation* refers to the treatment, removal, and reduction in contaminant mass at a site.
- *Mitigation* means taking measures to minimize or reduce contaminant exposure due to current site conditions.

Mitigation, by itself, usually does not directly affect the contaminant source area. The Middle River Complex (MRC) sub-slab depressurization (SSD) and treatment system is a mitigation measure. This was demonstrated by the observed quick rebound of VOC concentrations in the sub-slab after the planned shutdown of the Building A SSD system in March 2013. If the source contamination could be located and were remedied instead, rapid rebound would not be expected.

3.1 MANAGEMENT OF POSSIBLE ACUTE RISKS

The procedures presented in Section 3.1. apply if the performing contractor is on site and is responsible for managing the acute risk. If the incident was caused by others, the performing contractor may be requested or contracted to respond and assist in monitoring.

Acute risks are those that could immediately produce harmful effects. At the MRC, acute VI risks might be increased via several possible scenarios, including exceeding the occupational exposure levels for acute exposure for trichloroethene (TCE) and other COC; the intentional breaching of the facility slab in areas of sub-slab contamination; incidental cracking of the building slab; and changes in groundwater flow and contaminant shift triggered by water line leaks (as previously occurred in the Building A basement in 2014).

The performing contractor (currently Tetra Tech) attends building tenant meetings held every two weeks. Ongoing and future projects are discussed, and if work is planned by the performing contractor or the building tenants, that work is coordinated. Special consideration is given to activities that may increase VI potential. If necessary, LMC Properties, Inc., (LMCPI—property owner) and Lockheed Martin Environment, Safety and Health (ESH—the group responsible for environmental remediation at the MRC) will be informed, and will participate in the design, risk management, and coordination of work. Site tenants and employees are encouraged to report to ESH personnel if any modifications are planned that would breach the slab so that monitoring and additional mitigation measures can be considered.

By definition, managing acute risk from vapor intrusion requires a rapid response. Exceedance of the IA action levels for TCE or other SV COC would warrant resampling to confirm the exceedance. Possible immediate responses for acute risk associated with IA exceedances of action levels include vacating the premises to eliminate exposure and/or providing additional localized ventilation. Immediate action is especially important when potentially explosive gases, such as methane or petroleum hydrocarbons, are present; however, as previously stated, the possibility of this condition occurring at MRC is extremely limited. Where the possibility of explosive hazards exists, facility security, facility firefighting, the local fire department, and appropriate regulators should be alerted, per the site crisis and emergency plan (Tetra Tech, 2018).

Monitoring programs to manage potential acute risks will rely on direct-reading field instruments such as photoionization detectors (PIDs) and/or flame-ionization detectors (FIDs). (If a photoionization detector is used, a lamp of appropriate photon energy for the SV and IA chemicals of concern should be selected.) The direct-reading instruments cited have varying degrees of response to different chemicals; therefore, trigger levels must be developed based on instrument response. Draeger tubes or a portable gas chromatograph can be used if speciation of contamination is warranted.

Any location(s) where the slab has been compromised will be monitored by field instruments (and confirmed by a fixed-base laboratory, if samples are collected) to identify whether sub-slab contamination is migrating into the occupied space. The occupied space should also be monitored to assess airborne (breathing zone) concentrations of SV contaminants. If trigger levels are exceeded, then the area will need to be vacated until appropriate mitigation measures (e.g., localized ventilation) have been implemented.

3.2 MANAGEMENT OF POSSIBLE CHRONIC RISKS

If the results of SV and/or IA monitoring indicate possible unacceptable (i.e., exceeding trigger levels) chronic risks, a risk-management strategy will be developed to address these risks. These steps could include addressing building parameters, remediating groundwater and soil contamination, and communicating risks and management strategies to building occupants.

Mitigation techniques may be used individually or in combination as part of an overall plan. Several options exist to mitigate possible chronic risks, including:

- ***Sealing cracks/annular spaces around utilities, the floor/wall intersection, and/or cracks in basement floor or slab on grade:*** This measure uses nonvolatile epoxy-based sealants that are impenetrable to vapors. Although this approach may help reduce the flux rate at specific locations, it may be inadequate to eliminate vapor intrusion over a large slab.

- ***Sealing and venting groundwater sumps:*** Many buildings with basements have sumps intended to capture any unexpected water release (flooding, burst hose, etc.). These sumps are dug into the ground below the rest of the foundation and may serve as an easy access point for vapors. Sealing and venting them maintains their function while preventing vapor intrusion.

- ***Placing vapor barriers beneath the building:*** Vapor barriers can be plastic or geotextile sheeting, or perhaps a sealant, applied directly to the foundation and/or basement wall. Barriers are more easily installed during building construction than during a retrofit. This technique is often used in conjunction with active mitigation systems at sites with known contamination. Damage to even a small portion of the barrier during installation can result in significant leakage across the barrier.

- ***Reducing basement depressurization by ducting-in outside air for furnace combustion:*** For furnaces in basements, bringing outside air into the furnace decreases the pressure differential across the slab. Lowering the pressure differential in a basement lessens the pull on subsurface vapors into a structure.

- ***Over-pressurization of the building using air/air-heat exchangers:*** This technique creates a positive pressure in the building by supplying more outdoor air to the inside than the amount of air exhausted. To work effectively, buildings should be tightly sealed and have a ventilation system capable of producing the output needed to maintain the pressure differential. .

- ***Passive or active sub-slab depressurization systems:*** This technique creates a relatively lower pressure beneath the building foundation; the pressure differential is greater than that between the building foundation and the underlying subsurface. Thus, vapor is intercepted and prevented from migrating into the structure. Passive and active systems are very similar in design; the only real difference is inclusion of a powered fan to create a low-pressure zone for the active system. A passive depressurization system may not be particularly effective, because it lacks any means of actively moving vapors, relying instead on natural thermal and wind effects to move the soil gas from the collection zone to the external vent. Active systems have been installed in Buildings A and C, Block I.

- ***Ventilation of indoor air:*** This is a simple technique to increase airflow in a building (e.g., opening a bay door), immediately reducing contaminant concentrations.

- ***Air-purifying filters:*** If ventilation is not possible (e.g., in the Building A basement), air-purifying filters that remove chemical constituents from the air can be installed. Six air purifying filters treating 300 cubic feet of air per minute (each) are currently in use in the Building A basement. Air-purifying filters could also be used if ventilation would cause unacceptable (according to regulations) contamination outdoors or in other parts of the building.

Monitoring programs to assess possible chronic risks from VI are similar to the current semiannual IA and SV sampling and analysis being performed at MRC. The existing program can be expanded to address any newly identified areas of concern. Should mitigation steps not meet the goal of reducing SV and IA contaminant concentrations to regulatorily acceptable levels, remediation of affected media will be required.

Removing the source of vapors is often the preferred remediation strategy at vapor intrusion sites; however, this may not be an easy option at MRC. Feasibility is low given the size of the building footprints (80 acres), the scant knowledge of soil and groundwater contamination and of the nature and extent of vapor sources beneath the buildings, and the infeasibility of complete exploration of sub-slab conditions in buildings with active industrial operations. Short-term effects may be realized with soil removal and SV extraction, as these remediation actions either eliminate or reduce the source of contamination, or intercept the contaminated soil gas, thereby reducing exposure. Groundwater remediation is a long-term option that may require additional mitigation efforts to protect indoor air during remediation.

Implementing both a remediation and a mitigation strategy at the MRC site is not necessary now, but might be in the future as the USEPA keeps modifying, and often reducing, carcinogenic and noncarcinogenic chemical-specific toxicity values. For example, if risks were sufficiently high in currently occupied spaces, then some kind of mitigation measure, including ventilation, would be needed to immediately reduce exposure. However, since mitigation does not affect the source concentration, a remediation strategy may also be needed if additional mitigation measures do not reduce indoor air concentrations to less than risk-based concentrations.

The possible effects that proposed remedial alternatives might have on vapor intrusion should also be considered during remedy evaluation. Certain *in situ* remedies can change the chemical conditions of the subsurface, which could in turn increase the possibility of vapor intrusion. Degradation products that have more stringent screening levels than their parent compounds could be produced. These possibilities should be considered as part of risk management project planning.

In addition to mitigation and remediation, other risk management strategies, including land and building use-controls, could be necessary. If possible, areas of high risk could be vacated, and personnel could be moved to locations where risks are lower. Similarly, property located over a contaminant plume should not be developed unless mitigation measures, such as vapor barriers or vapor recovery piping, are installed under the building at the time of construction. Where groundwater contaminant concentrations are high, remediation measures should be instituted before building construction. Remediation measures are currently underway at three groundwater-plume locations (Block E, Block G, and Block I) with elevated trichloroethene concentrations.

Institutional and land use controls are common measures for limiting access and/or development to prevent and mitigate exposure to site contaminants. Institutional controls may be applied at undeveloped sites or at sites where land use may change in the future. Institutional controls might be necessary at MRC to ensure that the VI pathway is effectively addressed in the future. Institutional controls could include requirements to install engineering controls on buildings to mitigate possible VI pathways and to limit certain kinds of land use (such as residential use) that might pose regulatorily unacceptable health risks.

3.3 SSD SYSTEM FAILURES

SSD systems in Buildings A and C have operated since March 31, 2008 to maintain a vapor migration barrier. The SSD systems have removed VOC mass and have treated emissions with granular activated-carbon; a potassium permanganate zeolite (PPZ) treatment also occurs at Building C (only) for vinyl chloride. Operation, maintenance, and monitoring of the SSD systems have included biweekly system checks, quarterly system checks, and system maintenance, with monthly vapor sampling in Building A, and bimonthly vapor sampling in Building C.

Occasionally the SSD systems have been shut down due to a loss of power or mechanical problems (e.g., inoperable blower, increased system temperature). If such system failures occur, Table 3-1 provides troubleshooting matrices to solve the problem and restart the system. If the blower in the SSD system in either Building A or C is rendered inoperable and needs to be removed for repair or replacement, an available spare blower will be installed to minimize system downtime. The spare blower is stored in the Building C basement next to the Building C SSD system. The spare blower will operate until the primary system blower has been repaired, whereupon the spare will be returned to Building C for storage. An operations manual for the spare blower is in Appendix A.

The key goal of the SSD systems is to maintain a negative pressure below the slab (relative to the room space), thus minimizing VOC migration from the sub-slab soil into indoor air. VOC-mass removal occurs while vapor is drawn out to maintain the vacuum. When the SSD system fails, total VOC concentrations in SV rebound. Data collected since installation of the SSD systems, mainly from shutdown tests conducted in 2012 (Building C) and 2013 (Building A),indicate that an approximate five-fold increase in TCE and total VOC concentrations occurs upon soil vapor upon system shutdown, regardless of the length of system shutdown. Rebounding TCE concentrations in Building A soil vapor have occurred less than three days after system downtime in 2016, but concentrations detected during three subsequent tests did not increase significantly thereafter. Building C-system rebound was evident at monitoring points and in influent after one month in a single test; earlier sampling had not been conducted. If system failure occurs and the SSD system is inoperable for five days, the team will resample IA in those locations to determine whether the SSD system failure affects IA concentrations. Indoor air sampling efforts during previous SSD system shutdowns have not shown an effect.

3.4 COMMUNICATION OF POTENTIAL RISK

A critical aspect of VI projects/management is to communicate with building occupants, management, and regulatory agencies information relevant to possible health risks. VI has considerable potential to raise concerns among site occupants. Factors associated with VI, such as possible harm from exposure and associated health risks, and involuntary risk to exposure, likely contribute to workers' perceptions that a high level of risk exists, in spite of results indicating otherwise.

Investigation results must be effectively communicated to all stakeholders. These include, but are not limited to, Lockheed Martin, LMCPI, other tenants of the MRC, on-site employees, and Maryland Department of the Environment (MDE). The management group that represents tenants is kept informed during biweekly meetings as information becomes available. Annual employee poster sessions have been conducted, and meetings with smaller tenant operations are arranged when employees or management raise concerns. Reports and fact sheets are posted on the Lockheed Martin Corporation website and are housed in a repository at the local Essex Public Library. Likewise, tenants must inform LMCPI if chemical spills or leaks occur, and if they have plans that involve cutting the floor and installing utilities. In those cases, measures can be taken to ensure that workers are protected. Events that would trigger communication to stakeholders include:

- exceedance of an IA trigger level for TCE and the associated need for resampling
- exceedance of a sub-slab vapor (SV) screening level or trigger level for TCE
- exceedance of cumulative incremental lifetime cancer risk (ILCR) of 10^{-5} or a hazard index (HI) of 1
- planned shutdown or unintentional shutdown of SSD systems
- other relevant equipment failures associated with vapor intrusion mitigation (e.g., blowers)
- any opportunistic sampling that may result from breaching or opening the building slab

When the TCE concentration in IA exceeds its trigger level, Tetra Tech will notify the team upon receipt of preliminary data from the laboratory and convey the requirement to resample. Tetra Tech will notify the team of the resampling result upon receipt of preliminary data. If the TCE concentration continues to exceed the trigger level, the team will convey the results to relevant stakeholders.

In cases of SSD-system failures, fail-safe alarms will be triggered and Tetra Tech will be notified. Tetra Tech will respond to the alarm and restart the system within four hours of notification during daylight hours, or the following morning if the alarm occurs overnight. Tetra Tech will notify Lockheed Martin within 24 hours if the system remains shut down for more than one day. Lockheed Martin will also inform LMCPI when the system is shut down for more than one day.

3.5 SSD SYSTEM EXIT STRATEGY

An exit strategy is a plan for reducing risk from vapor intrusion to a level where no further remedial action or mitigation is needed. Monitoring may continue for a defined period to verify that response actions have been effective in reducing risks to acceptable regulatory levels. When monitoring shows this status has been achieved, the site will no longer require active management. At this point, Lockheed Martin must coordinate with MDE to establish a confirmation-sampling schedule before the systems are shut down (MDE, 2012). Although an SSDS may no longer be operating, Lockheed Martin will continue to attend tenant meetings, conduct monthly inspections to look for changes that may potentially result in exceedance of trigger levels, and consider yearly monitoring.

The SSDS exit strategy will incorporate the previously discussed trigger levels (Table 2-2) to clearly identify that the site no longer poses regulatorily unacceptable VI risk. As presented in Figure 2-2, if monitoring results indicate that SV and IA concentrations are less than trigger levels for two consecutive sampling rounds, then the SSD systems can be turned off, but only after obtaining concurrence from MDE. Rebound testing will be performed to determine whether SV or IA concentrations increase after systems are turned off.

Beginning approximately two weeks after shutdown, system influent and select monitoring points identified in a rebound-testing plan will be sampled monthly for up to six months. If SV concentrations are less than trigger levels after six months, then IA concentrations will be sampled. If these IA concentrations are less than trigger levels, SV and IA will be resampled after another six months. If SV and IA concentrations are less than trigger levels again, then the team should consider removing the SSD system. If SV and IA concentrations are less than trigger levels in some areas, but not in others, a phased exit strategy should be considered with respect to where individual system shutdowns may occur.

3.6 VI MONITORING EXIT STRATEGY

In buildings or locations where a SSDS is not in place (i.e., Building B of MRC), a multiple-lines-of-evidence approach may be used to demonstrate that VI monitoring of SV and IA is no longer necessary. Long term analytical results for shallow groundwater (if available), and SV and IA sampling results may be used to demonstrate that VOC concentrations have consistently been below all applicable screening levels. Depending on the strength of the lines of evidence, VI monitoring may either be eliminated or gradually reduced by either sampling less frequently or by targeting only select locations that have historically had the highest concentrations. MDE concurrence will be sought for either cessation or a reduction in VI monitoring, and monitoring exit strategy must also be communicated to MRC management and employees.

SECTION 4
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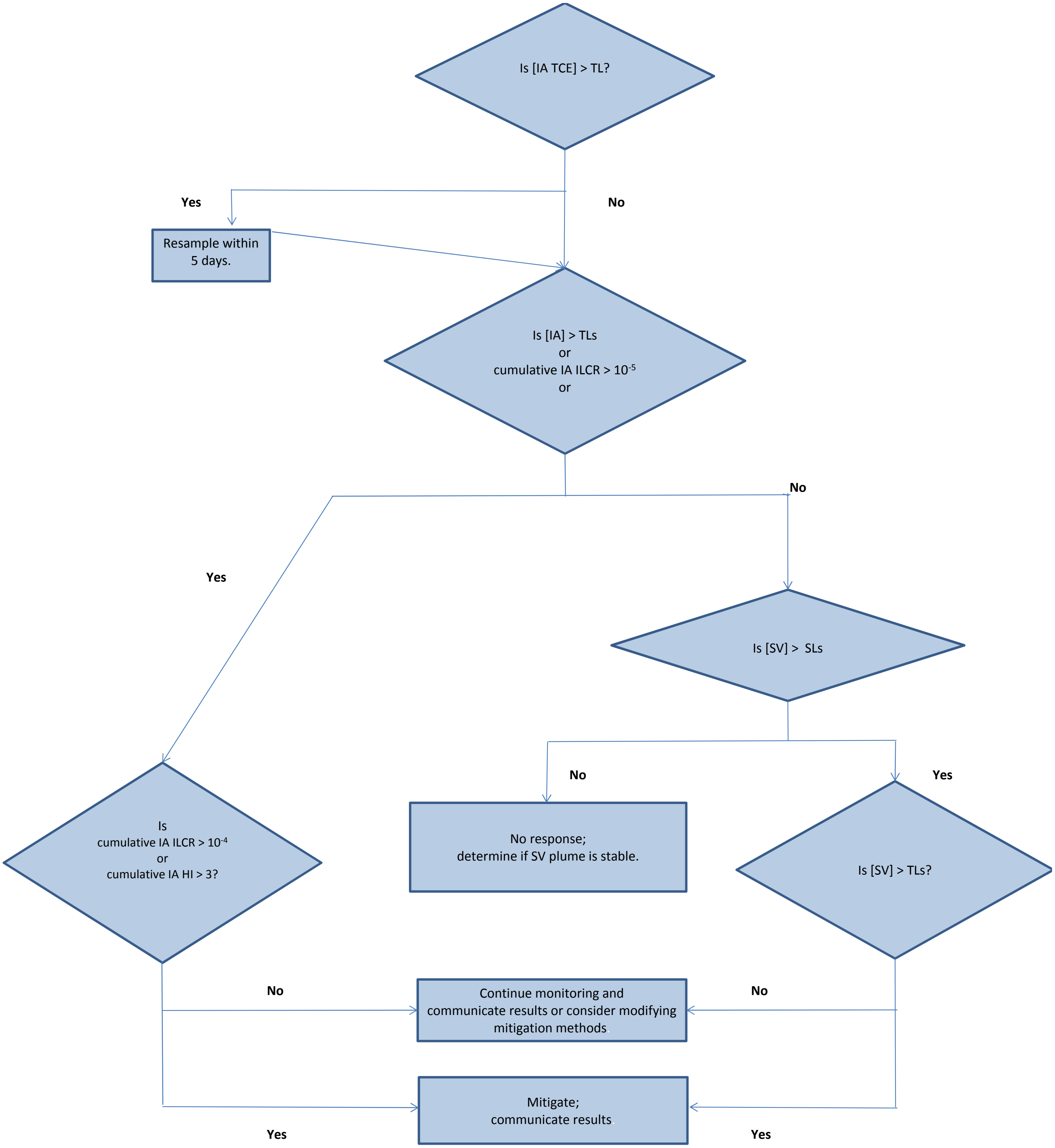
FIGURES

Figure 2-1 Trigger-Level Decision Matrix

Figure 2-2 SSD System Exit Strategy Decision Matrix

Figure 2-1

Trigger-Level Decision Matrix
Lockheed Martin Middle River Complex
Middle River, Maryland



HI	hazard index
IA	indoor air
[IA]	indoor air concentration
[IA TCE]	indoor air trichloroethene concentration
ILCR	incremental lifetime cancer risk
SL	screening level
SV	sub-slab vapor
[SV]	sub-slab vapor concentration
TL	trigger level

Figure 2-2

SSD System Exit-Strategy Decision Matrix
Lockeed Martin Middle River Complex
Middle River, Maryland

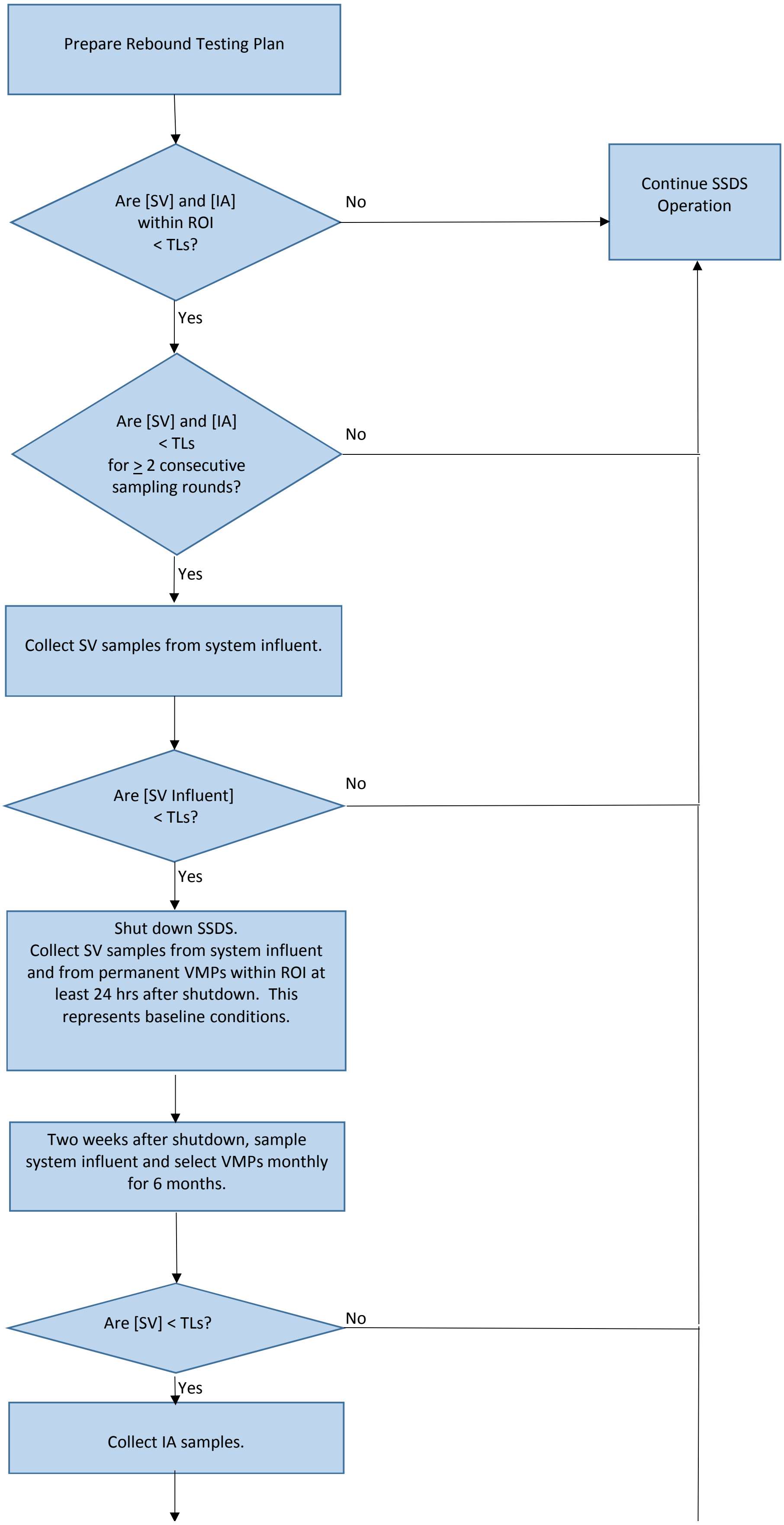
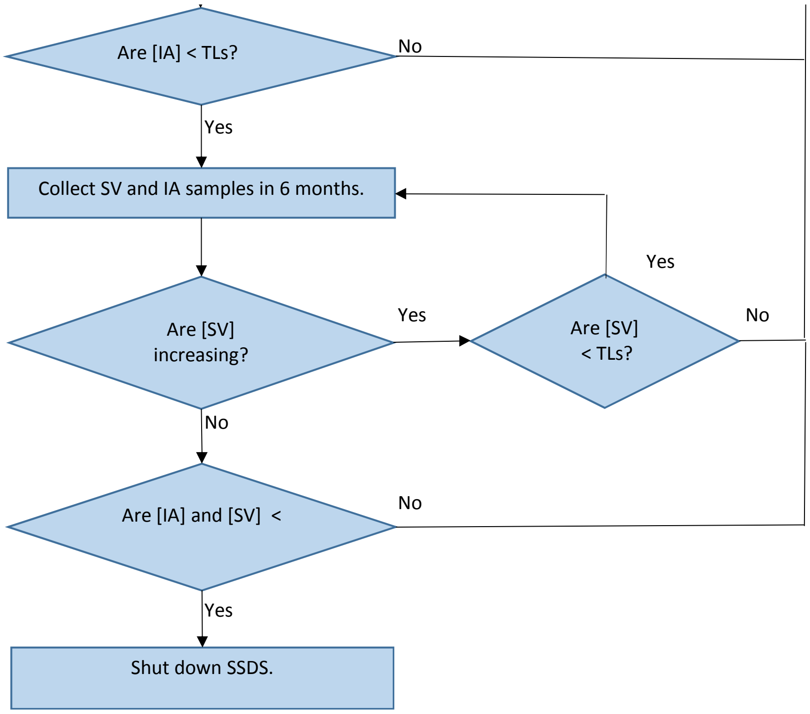


Figure 2-2

SSD System Exit-Strategy Decision Matrix
Lockeed Martin Middle River Complex
Middle River, Maryland



IA	indoor air	SV	sub-slab vapor
[IA]	indoor air concentration	[SV]	sub-slab vapor concentration
ROI	radius of influence	[SV Influent]	sub-slab vapor influent concentration
SSD	sub-slab depressurization	TL	trigger level
SSDS	sub-slab depressurization system	VMP	vapor monitoring point

TABLES

Table 2-1 Indoor Air and Sub-Slab Vapor Risk-Based Screening Levels for Indoor Workers

Table 2-2 Summary of Vapor-Intrusion Trigger Levels

Table 3-1 Possible System Failures and Troubleshooting Matrix, Buildings A and C Sub-Slab Depressurization Systems

Table 2-1

Indoor Air and Sub-Slab Vapor
Risk-Based Screening Levels for Indoor Workers
Lockheed Martin Middle River Complex
Middle River, Maryland

Chemical	10 x Carcinogenic Industrial Air USEPA RSL[1] (µg/m^3)	Noncarcinogenic Industrial Air USEPA RSL[2] (µg/m^3)	Indoor Air Screening Level[3] (µg/m^3)	Sub-Slab Screening Level[4] (µg/m^3)	Source
Benzene	1.6E+01	1.3E+02	1.6E+01	5.3E+02	Carcinogenic RSL (10^{-5} risk level)
Carbon tetrachloride	2.0E+01	4.4E+02	2.0E+01	6.7E+02	Carcinogenic RSL (10^{-5} risk level)
Chlorodifluoromethane	NA	2.2E+05	2.2E+05	7.3E+06	Noncarcinogenic RSL
Chloroform	5.3E+00	4.3E+02	5.3E+00	1.8E+02	Carcinogenic RSL (10^{-5} risk level)
Dichlorodifluoromethane	NA	4.4E+02	4.4E+02	1.5E+04	Noncarcinogenic RSL
1,1-Dichloroethane	7.7E+01	NA	7.7E+01	2.6E+03	Carcinogenic RSL (10^{-5} risk level)
1,2-Dichloroethane	4.7E+00	3.1E+01	4.7E+00	1.6E+02	Carcinogenic RSL (10^{-5} risk level)
1,1-Dichloroethene	NA	8.8E+02	8.8E+02	2.9E+04	Noncarcinogenic RSL
cis- 1,2-Dichloroethene[5]	NA	NA	NA	NA	*trans-* 1,2-dichloroethene used as surrogate
trans- 1,2-Dichloroethene[5]	NA	NA	NA	NA	USEPA withdrew reference concentration (2014).
Ethylbenzene	4.9E+01	4.4E+03	4.9E+01	1.6E+03	Carcinogenic RSL (10^{-5} risk level)
Methyl tert-Butyl Ether	4.7E+02	1.3E+04	4.7E+02	1.6E+04	Carcinogenic RSL (10^{-5} risk level)
Methylene chloride	1.2E+04	2.6E+03	2.6E+03	8.7E+04	Noncarcinogenic RSL
Naphthalene	3.6E+00	1.3E+01	3.6E+00	1.2E+02	Carcinogenic RSL (10^{-5} risk level)
Tetrachloroethene	4.7E+02	1.8E+02	1.8E+02	6.0E+03	Noncarcinogenic RSL
Toluene	NA	2.2E+04	2.2E+04	7.3E+05	Noncarcinogenic RSL
1,2,4-Trichlorobenzene	NA	8.8E+00	8.8E+00	2.9E+02	Noncarcinogenic RSL
1,1,1-Trichloroethane	NA	2.2E+04	2.2E+04	7.3E+05	Noncarcinogenic RSL
1,1,2-Trichloroethane	7.7E+00	8.8E-01	8.8E-01	2.9E+01	Noncarcinogenic RSL
Trichloroethene[6]	3.0E+01	8.8E+00	8.8E+00	2.9E+02	Noncarcinogenic RSL
Vinyl chloride	2.8E+01	4.4E+02	2.8E+01	9.3E+02	Carcinogenic RSL (10^{-5} risk level)
Xylene, *p-*	NA	4.4E+02	4.4E+02	1.5E+04	Noncarcinogenic RSL
Xylene, *m-*	NA	4.4E+02	4.4E+02	1.5E+04	Noncarcinogenic RSL
Xylene, *o-*	NA	4.4E+02	4.4E+02	1.5E+04	Noncarcinogenic RSL

[1] Corresponds to a risk level of 1 x 10^{-5}. (10 times the carcinogenic RSL)

[2] Corresponds to a hazard quotient of 1.0

[3] Lesser of ten times the carcinogenic industrial air RSL (10^{-5} risk level) and the noncarcinogenic industrial air RSL

[4] Sub-slab screening level = indoor air screening level divided by an attenuation factor of 0.03

[5] The RSL for cis- and trans-1,2-dichloroethene were withdrawn in 2014 because the reference dose was withdrawn from IRIS.

[6] A site-specific screening level of 35 µg/m3 for indoor air has been derived for the Building A Basement based on limited exposure potential in the basement.

IRIS = USEPA Integrated Risk Information System

µg/m^3 = micrograms per cubic meter

NA = not available

RSL = regional screening level

USEPA = United States Environmental Protection Agency

Source:. *Regional Screening Levels for Chemical Contaminants at Superfund Sites* . USEPA Office of Superfund and Oak Ridge National Laboratory. May 2016.

Table 2-2

Summary of Vapor Intrusion Trigger Levels
Lockheed Martin Middle River Complex
Middle River, Maryland

Chemical	Indoor air trigger level (μg/m^3)	Sub-slab vapor trigger level (μg/m^3)
Benzene	1.6E+01	1.6E+03
Carbon tetrachloride	2.0E+01	2.0E+03
Chlorodifluoromethane	2.2E+05	2.2E+07
Chloroform	5.3E+00	5.3E+02
Dichlorodifluoromethane	4.4E+02	4.4E+04
1,1-Dichloroethane	7.7E+01	7.7E+03
1,1-Dichloroethene	4.7E+00	4.7E+02
1,2-Dichloroethane	8.8E+02	8.8E+04
cis-1,2-Dichloroethene	NA	NA
trans-1,2-Dichloroethene	NA	NA
Ethylbenzene	4.9E+01	4.9E+03
Methyl tert-Butyl Ether	4.7E+02	4.7E+04
Methylene chloride	2.6E+03	2.6E+05
Naphthalene	3.6E+00	3.6E+02
Tetrachloroethene	1.8E+02	1.8E+04
Toluene	2.2E+04	2.2E+06
1,2,4-Trichlorobenzene	8.8E+00	8.8E+02
1,1,1-Trichloroethane	2.2E+04	2.2E+06
1,1,2-Trichloroethane	8.8E-01	8.8E+01
Trichloroethene	8.8E+00	8.8E+02
Vinyl chloride	2.8E+01	2.8E+03
Xylenes, total	4.4E+02	4.4E+04

Table 3-1

Possible System Failures and Troubleshooting Matrix
Buildings A and C Sub-Slab-Depressurization Systems
Lockheed Martin Middle River Complex, Middle River, Maryland
Page 1 of 2

Issue	Possible causes	Possible remedies
Power failure(1,3)	• Power loss to building • Severe storm/lightning • Utility work	• The sub-slab-depressurization (SSD) system will shut down in the event of a power failure. The low-vacuum switch will alarm upon system shutdown and the auto-dialer will call the system operator. When power to the control panel has been restored, the SSD system in Building A will automatically restart. The system in Building C will not restart automatically when power is restored.
Blower is not operating(1,3)	• Breaker in service panel has been tripped. • Breaker in service panel is in OFF position • An alarm condition exists. See issues and remedies below. • An alarm switch is faulty. • The blower fan has stopped. • The blower is damaged.	• Turn breaker in service panel to ON position. • Push reset button on breaker. • Remedy the alarm condition. See issues and remedies below. • Repair or replace the faulty alarm switch. • Confirm damage by manually trying to rotate fan. If fan will not manual spin, contact system installation subcontractor (S&S Technologies, Inc.). • If it is determined that the blower needs to be taken off-line for troubleshooting/repair, the spare blower in the Building C basement can be installed to restart either system. Refer to Appendix A for the procedures.
High-temperature alarm (1,3)	• Clogged air filter or line • Low airflow • Faulty temperature-switch	• Change air filter and continue system operation or clear obstruction. • Reduce pressure differential across blower. • Check temperature switch; clean, adjust, or replace if necessary.
Moisture Separator High-level alarm (1,2,3)	• Moisture separator is full of condensate. • Faulty level-switch	• Drain moisture separator. • Close extraction trenches in the Building A basement during periods of heavy rain until water levels decrease. • Check level switch; clean or replace if necessary.

Table 3-1

Possible System Failures and Troubleshooting Matrix
Buildings A and C Sub-Slab-Depressurization Systems
Lockheed Martin Middle River Complex, Middle River, Maryland
Page 2 of 2

Issue	Possible causes	Possible remedies
High-pressure alarm(1,3)	• Granular activated-carbon drums are moist/wet. • Faulty pressure-switch. • Effluent pipe valve is partially closed.	• Replace carbon drum. • Check pressure switch; adjust, clean or replace if necessary. • Ensure that effluent pipe valve is fully open.
Low-pressure alarm (Building A) (1,3)	• Low or no flow due to closed/partially closed vapor extraction points. • Low or no flow due to water in the lines. • Faulty pressure-switch. • Pipe or hose disconnected or broken.	• Ensure that a sufficient number of vapor extraction points are open to allow enough flow. Check blower. • Check lines for water and drain if necessary. • Repair or replace switch. • Repair or replace pipe or hose.
Low-pressure alarm (Building C) (1,3)	• Low or no flow due to water in the lines. • Faulty pressure-switch • Pipe or hose disconnected or broken.	• Check lines for water and drain if necessary. • Repair or replace switch. • Repair or replace pipe or hose.

(1) Triggering any of the fail-safe alarms listed in the above table will also trigger the system auto-dialer to call the system operator and up to three backup personnel, until the alarm has been acknowledged (by pressing 555 on the phone’s keypad). Tetra Tech, Inc. (Tetra Tech) will respond to the alarm and restart the system within four hours of notification during daylight hours, or the following morning if the alarm occurs overnight, if reasonably possible. Lockheed Martin Corporation (Lockheed Martin) will be notified within 24 hours if the system remains shut down for more than one day, and will be given a description of the cause(s) and actions taken to address the condition and restart the system.

(2) Note that at times of high precipitation, the SSD system extraction trenches in the Building A basement may be shut down until water levels decrease to avoid excessive water extraction by the system, as vapor cannot be effectively extracted under these conditions. Lockheed Martin will be notified if this action is required. The trenches will be reopened when basement water levels decrease (determined visually and by system testing).

(3) Tetra Tech personnel can also call the SSD system auto-dialers at 443-510-1622 (Building A) and 443-510-1487 (Building C). Calling this number will provide the status of alarms, power, battery, and sound.

APPENDICES

Appendix A—Spare Blower Installation and Operation

APPENDIX A

SPARE BLOWER INSTALLATION AND OPERATION

Sub-Slab Depressurization Systems

Lockheed Martin Middle River Complex
2323 Eastern Boulevard, Middle River, MD

1.0 INTRODUCTION AND PURPOSE

An AMETEK® Rotron® model DR858 blower was purchased in December 2016 to function as a spare blower if the blower in the sub-slab depressurization system (SSDS) operating in Building A or in the Building C SSDS becomes inoperable and needs to be removed for repair or replacement. The spare blower is a 7.5 horsepower (HP) regenerative blower, AMETEK® Rotron® model **DR858**[1], capable of achieving a suction flow-rate of 220 standard cubic feet per minute (SCFM) at 55 inches water column (WC) and is capable of operating in both Building A and Building C systems.

The spare blower is stored in the Building C basement next to the Building C SSD system. The spare blower will be used until the primary system blower is repaired and will then be moved back to Building C for storage. This document provides guidance for the installation, operation, and maintenance (O&M) of the spare blower.

1.1 SPARE BLOWER INSTALLATION, OPERATION, AND MAINTENANCE

The following steps will be followed to install the spare blower in the SSDS system:

1. Schedule S&S Technologies, Inc. (original system installation subcontractor) to assist with removal of the primary blower and installation of the spare blower.

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[1] http://catalog.ametekdfs.com/pdf/ROTRON%20Regenerative%20Blowers%20DR858_CP858%2010.0HP.pdf

2. Shut off power to the SSDS following proper lockout/tagout procedures, as referenced in Section 6 of the operation and maintenance manuals for Buildings A (Tetra Tech, 2019a) and C (Tetra Tech, 2019b).
3. Disconnect conduit and wiring of primary system blower.
4. Detach and remove system inlet and discharge piping.
5. Unscrew blower foundation bolts.
6. Procure forklift and lift primary blower free of system via chain secured at blower anchor points.
7. Install replacement blower by lowering the blower onto the skid.
8. Secure the spare blower via the foundation bolts.
9. Re-reconnect the system inlet and discharge piping, conduit and wiring, and power on the skid.
10. Inspect rotation of blower fan to ensure it moves in the correct direction.
11. Follow the system startup procedures in Section 4 (System Startup and Shutdown Procedures) of the system's operation and maintenance manual.

1.2 OPERATION AND MAINTENANCE

The operation and maintenance procedures specified in the SSDS operation and maintenance manual are to be followed while the system operates using the spare blower. Blower information and maintenance details are summarized in the following table. The blower's manufacturer cut sheet and operation and maintenance manual is attached.

Manufacturer	**Supplier**	**Model**	**Specification/ set point**	**Required maintenance**
AMETEK® Rotron® 627 Lake Street Kent, Oh. 44240 Tel: 330-673-3452	J. E. Gasho 460 West Gay Street West Chester, Penn. 19380 Tel: 610-692-5650	DR858AY72W	7.5HP 460-Volt 3-phase 220 SCFM at 55 inches WC	*Every two weeks:* • Check and record operating temperature. *Quarterly:* • Inspect general condition of blower and surrounding piping for leaks. • Measure and record amperage draw.

2.0 REFERENCES

Tetra Tech, Inc. (Tetra Tech), 2019a. *Operation, Maintenance and Monitoring Manual, Sub-Slab Depressurization System Building A, Lockheed Martin Middle River Complex, 2323 Eastern Boulevard, Middle River, Maryland.* Prepared by Tetra Tech, Inc., Germantown, Maryland for Lockheed Martin Corporation, Bethesda, Maryland. March.

Tetra Tech, Inc. (Tetra Tech), 2019b. *Operation and Maintenance Manual: Sub-Slab Depressurization System-Building C, Lockheed Martin Middle River Complex, 2323 Eastern Boulevard, Middle River, Maryland.* Prepared by Tetra Tech, Inc., Germantown, Maryland for Lockheed Martin Corporation, Bethesda, Maryland. March