Vapor Intrusion Management Plan
Lockheed Martin Middle River Complex
2323 Eastern Boulevard
Middle River, Maryland

Prepared for:

Lockheed Martin Corporation

Prepared by:

Tetra Tech, Inc.

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Michael Martin, P.G.
Regional Manager

[redacted]

Eric M. Samuels
Project Manager

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ACRONYMS

µg/m^3	microgram(s) per cubic meter
AF	attenuation factor
atm-m^3/mol	atmospheres per cubic meter/mole
ca	carcinogenic
DTSC	California Department of Toxic Substances Control
ESH	environment, safety, and health
eV	electron volt(s)
FID	flame ionization detectors
HQ	hazard quotient
HVAC	heating, ventilation, and air conditioning
IA	indoor air
IAQ	indoor air quality
Lockheed Martin	Lockheed Martin Corporation
MDE	Maryland Department of the Environment
MRC	Middle River Complex

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Section 1
Introduction

a site, or if it might reasonably be assumed that they have been used or released at a site. Typically, the potential for vapor intrusion is evaluated during a site investigation.

The site-specific vapor intrusion risk assessment for the Middle River Complex indicates the potential for regulatorily unacceptable risks associated with vapor intrusion; appropriate response actions were implemented to mitigate these risks. Reasonable alternatives are considered when selecting response actions, including passive or active ventilation systems, floor sealants, or other mitigation measures. The potential for vapor intrusion in future structures should be addressed during design; any necessary measures to reduce vapor intrusion, including the associated construction costs for these measures, should also be included in the design. A typical approach for assessing potential risks posed by the vapor intrusion pathway, including its mitigation and remediation options, is summarized below:

Evaluate whether exposure to the vapors poses an acute (immediate) risk to building occupants: This can include both acute health risks and the risk of 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 4.1). If acute risks from vapor intrusion are identified, the affected area may need to be evacuated until the risks are mitigated. If no acute risks are identified, a screening-level vapor intrusion evaluation may be conducted.

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) risk-based screening values. If site concentrations are below screening levels, a low potential for vapor

Evaluate mitigation/remediation options, if necessary: Mitigation involves techniques that

Indoor air quality monitoring has been ongoing since 2006 for Middle River Complex Buildings A, B, and C. The results of the first monitoring round (in December 2006) for the vertical-launch system (VLS) facility indicated no need for additional sampling there, as no analyzed constituents had been detected in the facility above their applicable screening levels (Tetra Tech, 2007). Analytical results for Buildings A, B, and C indicated that some (but not all) chemicals of concern (COC) identified in the subsurface have also been detected in background and indoor air samples. Background (outdoor air) samples, collected at the four corners of the facility property, are used to measure on-site concentrations of chemicals that may be attributable to non-facility sources; they are also used to identify possible chemical contributions from site operations.

Indoor air quality data for the chemicals of concern were compared to risk-based screening levels derived using conservative U.S. Environmental Protection Agency default exposure assumptions and toxicity values. These analyses indicated that most of the volatile organic compounds detected in indoor air quality samples are probably *not* associated with sub-slab vapor intrusion. Migration of sub-slab vapor into indoor air may be occurring in limited locations. Trichloroethene in indoor air quality samples may be associated with sub-slab vapor migration at the Building A Plating Shop and in the Building C Basement, since it has co-occurred with a marker chemical (cis-1,2-dichloroethene) found only in sub-slab vapor samples. The chemical cis-1,2-dichloroethene is considered a marker of possible sub-slab vapor intrusion because it is not a manufactured chemical and is only found when other chlorinated compounds such as trichloroethylene break down.

The results of the first three rounds of monitoring led the project team to recommend mitigation for locations where chemicals in sub-slab vapor were known to be at concentrations above performance of the sub-slab depressurization (SSD) systems, and provide ongoing protection of worker health and safety with respect to potential vapor intrusion.

whether mitigation is required

whether or when an emergency response is indicated

2.2 DEVELOPMENT OF VI AND IAQ TRIGGER LEVELS

The default screening levels for industrial air (indoor air) set forth in USEPA's *Regional Screening Levels for Chemical Contaminants at Superfund Sites* (USEPA, 2011a) are currently used to evaluate the contaminants identified in the semi-annual SV and IAQ sampling events at the MRC; Table 2-1 presents a summary of these indoor air values. USEPA generates both carcinogenic (*ca*) and noncarcinogenic (*nc*) screening levels; the lowest of these is used to screen a given contaminant's detected concentration in SV after being divided by an attenuation factor of 0.03 to take into account the dilution that would occur in the indoor air. The attenuation factor represents the factor by which subsurface-vapor concentrations migrating into indoor air spaces are assumed to be reduced due to diffusive, advective, and/or other attenuating mechanisms. Simply stated, the soil gas is expected to get diluted on migration into indoor air; so the attenuation factor is the ratio of the indoor air concentration of a constituent to its subsurface vapor concentration under a conservative vapor intrusion scenario.

Although USEPA screening levels are calculated using a carcinogenic risk level of 1 10^{-6} (or one in one million), carcinogenic risk at the MRC is evaluated at the 1 10^{-5} (orc0

2,600 µg/m^3 was established for methylene chloride in industrial air. This is the lowest of the carcinogenic/noncarcinogenic values for methylene chloride, and is based on noncarcinogenic effects. This value is used to screen the IAQ results in anticipation of MDE adopting the updated USEPA guidance. The previous screening value had been 261 µg/m^3.

USEPA updated its toxicological review for tetrachloroethene (PCE) in February 2012 (USEPA, 2012a); as part of this document, new toxicity criteria were published on IRIS. The new criteria established a screening value of 175 µg/m^3 for PCE in industrial air (USEPA, 2012a). This is the lowest of the carcinogenic/noncarcinogenic values for PCE, and is based on noncarcinogenic effects. This value is used to screen the IAQ results in anticipation of MDE adopting the updated USEPA guidance. The previous screening value had been 20.8 µg/m^3. These updated screening levels reflect USEPA's review and incorporation of the most recent toxicity data for these compounds.

In the past, these default screening values were used to evaluate historical data collected as part of ongoing investigations at Block I. Concentrations of chemicals detected in SV were compared to their respective screening values, which were derived in accordance with methods discussed in Appendix D of USEPA's *Draft Guidance for Evaluating the VI to Indoor Air Pathway from Groundwater and Soils* (USEPA, 2002). SV screening values were calculated by dividing the default IAQ screening levels (shown in Table 2-1) by a conservative attenuation factor (AF) of 0.1.

rather than ambient air (background) concentrations, were the primary data source used to calculate attenuation factors.

Attenuation factors were developed and compared for all residences, residences with basements, and residences with slab-on-grade. These comparisons indicated that the sub-slab attenuation factors for residences with basements are generally similar to those for residences with a slab-on-grade foundation. As expected, the median sub-slab soil-gas attenuation factors for commonly encountered chlorinated VOCs are quite similar, as are the 95th percentile values.

These observations are consistent with the conceptual model of vapor intrusion, which predicts that chemicals with similar fate and transport properties (such as chlorinated VOCs) would be expected to have similar attenuation factor values. This study suggests that USEPA will use an AF of 0.03 in its revised vapor intrusion guidance (USEPA, 2012b). There is greater confidence in this new value compared to the previously used default value of 0.1 because the new value is based on a large database that was specificalthvattese7(c) oimsefth3(b)-3.r conenaThs7(c)lt v.6(lo)-.0(a)121 historically used at the MRC, and the objectives of applying the trigger levels, the current risk-based IAQ screening levels will also be used as the trigger levels for IA (see Table 2-2).

2.2.2 Sub-Slab Vapor Trigger Level Calculations

The intent of establishing the SV trigger levels is to identify contaminant concentrations when they are sufficiently low so that decisions regarding possible intervention can be made. SV trigger levels were developed by first dividing the IAQ trigger levels discussed in Section 2.2.1 by the default AF of 0.03, and then applying an additional multiplying factor of 3. This is considered protective of human health, as there is currently no known direct exposure of the working population to sub-slab vapors, even though actual SV levels in some cases have been more than one order of magnitude above the trigger level for TCE. In fact, there is no definitive evidence that SV levels correlate in any way to IAQ levels, despite multiple sampling events over the past six years.

Historical data indicate that the slab at the MRC has been effective in controlling or even preventing SV migration, since IAQ concentrations have typically been orders of magnitude less than corresponding SV concentrations. The MRC has demonstrated elevated concentrations of SV VOCs in the past; however, concentrations of SV contaminants in IA have rarely been above screening levels. As such, the use of a trigger value higher than the sub-slab screening value is considered appropriate given historical site-specific findings at the MRC (Table 2-2). 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 mitigation has been conducted over the past five years, and in areas where additional mitigation is proposed in the near future. SV contribution to IA is not anticipated. However, monitoring and analysis will continue across the Block I buildings, and additional mitigation will be proposed in the future if determined necessary.

2.2.3 Application of Trigger Levels

If contaminant concentrations in SV and IAQ have not increased during the shutdown period and are still below trigger levels, then the decision may be made to remove the system. If the contaminant concentrations in SV show a clear increasing trend from baseline conditions, but are still below trigger levels, then the rebound test should continue; contaminant concentrations may continue to increase, or merely fluctuate with more 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 the rebound test should be performed again after SV and/or IAQ monitoring results have produced concentrations below the trigger levels for a minimum of three consecutive months. The date of the new rebound test will be determined based on site-specific SV concentrations and trends.

Table 2-1

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

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	1.57E+01	1.57E+03
Carbon tetrachloride	2.04E+01	2.04E+03
Chlorodifluoromethane	2.19E+05	2.19E+07
Chloroform	5.33E+00	5.33E+02
Dichlorodifluoromethane	4.40E+02	4.40E+04
1,1-Dichloroethane	7.67E+01	7.67E+03
1,1-Dichloroethene	4.72E+00	4.72E+02
1,2-Dichloroethane	8.76E+02	8.76E+04
cis-1,2-Dichloroethene	2.63E+02	2.63E+04
trans-1,2-Dichloroethene	2.63E+02	2.63E+04
Ethylbenzene	4.91E+01	4.91E+03
Methyl tert-Butyl Ether	4.72E+02	4.72E+04
Methylene chloride	2.60E+03	2.60E+05
Naphthalene	3.61E+00	3.61E+02
Tetrachloroethene	1.75E+02	1.75E+04
Toluene	2.19E+04	2.19E+06
1,2,4-Trichlorobenzene	8.76E+00	8.76E+02
1,1,1-Trichloroethane	2.19E+04	2.19E+06
1,1,2-Trichloroethane	7.67E+00	7.67E+02
Trichloroethene	8.80E+00	8.80E+02
Vinyl chloride	2.79E+01	2.79E+03
Xylenes, total	3.07E+03	3.07E+05

FIGURE 2-1
TRIGGER LEVEL DECISION MATRIX
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

Carcinogenic risk < 10^{-6}
Hazard quotient <1

Carcinogenic risk < 10^{-5}
Hazard quotient <1

Carcinogenic risk ≥10^{-6} but < 10^{-5}

reducing sub-slab and indoor air 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 VI sites. Greater short-term effects may be seen with soil removal and soil-vapor extraction, as they either eliminate or reduce the source of contamination, or intercept the contaminated soil gas, thereby

TABLE 3-1

ACTION LEVELS FOR ACUTE EXPOSURE
LOCKHEED MARTIN MIDDLE RIVER COMPLEX
MIDDLE RIVER, MARYLAND

Chemical	CAS #	Occupational Exposure Limit (OEL)	OEL Reference	Can this chemical be monitored by a FID?	Can this chemical be monitored by a PID (RAE)?	Lamp strength for PID (eV)	# of Exposures allowed in any one work day	Time per Exposure (mins)	PID ACTION LEVEL/ INSTRUMENT READING (ppm)	FID ACTION LEVEL/ INSTRUMENT READING (ppm)
1,1,1-Trichloroethane	71-55-6	450	ACGIH 15 min STEL	yes	yes	11.7	1	3	2250	350
1,1-Dichloroethane	75-34-3	100	OSHA TWA8	yes	no	NA	1	3	NA	3750
1,1-Dichloroethene	75-35-4	5	ACGIH TWA8	yes	yes	10.6	1	3	650	45
1,2-Dichloroethane	107-06-2	100	OSHA Ceiling	yes	yes	11.7	1	any	60	80
1,2-Dichloroethene - cis	156-59-2	200	OSHA TWA8	yes	yes	10.6	1	3	22000	2400
1,2-Dichloroethene - trans	156-60-5	200	OSHA TWA8	yes	yes	10.6	1	3	14000	2400
Benzene	71-43-2	2.5	ACGIH STEL	yes	yes	10.6	1	3	6.5	2.75
Carbon Tetrachloride	56-23-5	25	OSHA Ceiling	yes	yes	11.7	1	any	42	2.5
Chlorodifluoromethane	75-45-6	1000	ACGIH TWA8	yes	no	NA	1	3	NA	64000
Chloroform	67-66-3	50	OSHA Ceiling	yes	yes	11.7	1	3	175	32
Dichlorodifluoromethane	75-71-8	1000	OSHA TWA8	yes	no	NA	1	3	NA	24000
Ethylbenzene	100-41-4	125	ACGIH STEL	yes	yes	10.6	1	3	325	625
Methyl tert-Butyl Ether (MTBE)	1634-04-4	40	ACGIH TWA8	no	yes	10.6	1	3	5575	NA
Methylene Chloride	75-09-2	125	OSHA 15 minute STEL	yes	yes	11.7	1	3	445	90
Naphthalene	91-20-3	100	OSHA TWA8	no	yes	10.6	1	3	6500	N/A
Tetrachloroethylene	127-18-4	200	OSHA Ceiling	yes	yes	10.6	1	any	114	140
Toluene	108-88-3	300	OSHA Ceiling	yes	yes	10.6	1	any	150	330
Trichlorobenzene, 1,2,4-	120-82-1	5	ACGIH Ceiling	no	yes	10.6	1	any	2.3	NA
Trichloroethane, 1,1,2-	79-00-5	10	OSHA TWA8	yes	yes	11.7	1	3	1400	1300
Trichloroethene	79-01-6	200	OSHA Ceiling	yes	yes	10.6	1	any	108	140
Vinyl Chloride	75-01-4	5	OSHA 15 minute Ceiling	yes	yes	10.6	1	3	50	1.25
Xylene	106-42-3	150	OSHA 15 minute STEL	yes	yes	10.6	1	3	290	120

ACGIH - American Conference of Governmental Industrial Hygienists
15 min STEL - 15 Minute Short Term Exposure Limit
OSHA Occupational Safety and Health Adminstration Eight Hour Time Weighted Average
TWA 8 -Eight Hour Time Weighted Average
Ceiling - Ceiling Limit
FID - flame ionization detector
PID - photo ionization detector
any - instantaneous exposure requiring immediate exit

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Section 4
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