COMPREHENSIVE HUMAN HEALTH RISK ASSESSMENT
AND
RISK MANAGEMENT EVALUATION
FOR THE RIGGS PARK COMMUNITY,
DISTRICT OF COLUMBIA

Prepared for:

District Department of the Environment
District of Columbia

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LIST OF EXHIBITS

Additional Exhibits are presented in Appendix A, Appendix B, and Appendix C and are presented as part of the analysis tables.

1.0 EXECUTIVE SUMMARY

This comprehensive human health risk assessment (HHRA) and risk management evaluation for the Riggs Park community was conducted to evaluate current and potential future cancer risks and noncancer health hazards associated with potential vapor intrusion into 106 homes located in the Riggs Park neighborhood in northeast Washington D.C. This HHRA is a revision of the HHRA which was prepared in 2009 for the same community. The 2009 HHRA did not include a correlational study between sub-slab vapor samples and groundwater data, or present an evaluation for the 12 homes located on the water table. This HHRA presents both of those evaluations. The primary goal of this HHRA is to determine whether vapor concentrations detected in sub-slab vapor samples areassociated with contaminated groundwater, thereby posing unacceptable noncancer health hazards or cancer risks based on long-term inhalation exposures. Homes in which health risks are unacceptable will be targeted for remediation.

Studies of the uncontrolled chemical release into groundwater from the former Chevron Facility, located at 5801 Riggs Road in Chillum, Prince George's County, Maryland, have been ongoing since November 1989. Although the initial focus of investigations at the site was petroleum-related chemicals, this investigation is comprehensive and evaluates all chemicals detected in sub-slab vapor samples. Sub-slab samples are considered the most reliable data for vapor intrusion investigations where the vapors originate from contaminated groundwater under the home. According to EPA (2002[1], 2009a[2]) chemicals detected in sub-slab vapor samples can be attributed only to contaminated groundwater because chemicals used by the homeowner do not typically migrate downward into the subslab space. This assumption was verified in this investigation with a detailed analysis in which the chemicals detected in an indoor air sample were compared to the chemicals detected in the sub-slab sample for each home.

All chemicals detected in subslab samples were initially identified as "chemicals of *potential* concern" (COPCs). No chemical was excluded based on an *a priori* assumption of what chemicals "should" be attributable to groundwater contamination. While previous investigations focused on gasoline constituents, namely benzene, toluene, ethylbenzene and xylene (commonly referred to as BTEX) and tetrachloroethene [(PCE), which is used in dry cleaning and for cleaning automobile parts]—the current investigation comprehensively assessed the health threat for all detected chemicals. In this HHRA, a "chemical of concern" (COC) was defined as a chemical detected in a sub-slab sample at a concentration corresponding to a cancer risk $\geq 1\text{x}10^{-5}$ or a hazard index $\geq$1.0.

For homes where sub-slab vapor samples were collected, human health risks were calculated according to EPA guidance (1989[3], 2002[1]). After calculating risks, a groundwater source analysis was conducted to determine if the chemical(s) posing unacceptable risk(s) was associated with groundwater contamination. The risk assessment together with the groundwater source analysis formed the basis of the risk management decision for each home. The threshold criterion for homes requiring remediation was that a COC be detected in at least one subslab sample at a concentration that posed a cancer risk $\geq 1\text{x}10^{-5}$ or a hazard index $\geq$ 1.0. The second criterion was that there must be a demonstrated link between the COC detected in the subslab sample and groundwater contamination near the home. The rationale underlying the risk management decision to recommend remediation only in homes satisfying these two criteria is based on the concept of effective "risk mitigation." One of the basic assumptions of the risk assessment is that residents must be exposed to chemicals for a lengthy period of time (years) for the risks to be applicable. Without a groundwater source providing a "reservoir," or continuous source, the calculated risks are not truly representative of cancer risk. For example, a brief or transient increase in the chemical concentration in the sub-slab space would not satisfy the requirement necessary for cancer risk. It is noteworthy that while the cumulative cancer risk exceeded the $1x10^{-5}$ benchmark at numerous homes, no link to groundwater contamination could be identified in many of those homes. Consequently, the calculated cancer risk is not applicable.

For homes where sub-slab samples were not collected (which precluded calculating risks), a different risk management paradigm was applied to evaluate the likelihood of potential health threats. In lieu of sub-slab samples, it was necessary to rely on other evidence of possible vapor intrusion. For example, homes in direct contact with contaminated ground water or that fell within kriged boundaries delineating clusters of homes with unacceptable sub-slab vapor concentrations were identified as homes requiring remediation. Additionally, any duplex home from which no samples were collected and which shared a common concrete slab with a home already targeted for remediation (based on a high sub-slab sample vapor concentration) was automatically identified as requiring remediation.

In the final analysis, it was determined that 43 homes require remediation. Nineteen homes require remediation because unacceptable concentrations of PCE were detected in sub-slab vapor samples. Remediation is also warranted for an additional 8 homes that were located within an area bounded by a kriging analysis. Twelve homes that shared a common basement slab with homes targeted for remediation were also added. Lastly, 3 homes require remediation due to unacceptable chloroform concentrations detected in sub-slab vapor samples and 1 home was in direct contact with groundwater contaminated with volatile organic compounds.

2.0 RISK ASSESSMENT METHODS

A comprehensive HHRA was conducted for 106 Riggs Park homes where sub-slab vapor sample were collected. The goal of the HHRA is to determine whether vapor intrusion poses unacceptable cancer risk and/or adverse noncancer health effects. The HHRA results were used to determine if remediation is warranted for any of the 106 homes.

The risk assessment methods used in this HHRA conform to U.S. EPA risk assessment/management guidance and policy. All health risks were calculated on the basis of the vapor concentrations measured in sub-slab samples that were collected in 2008 by the District Department of the Environment's (DDOE) contractor, S. S. Papadopulos & Associates (SSP&A 2008). By solely focusing on the sub-slab samples, it can be concluded that the detected chemicals are arising from a source under the home and that there are no ambient household chemicals confounding the interpretation of sub-slab sampling results.

A total of 357 vapor port samples were collected in 2008, and the health hazard and cancer risk were calculated for each of those samples. This HHRA presents the following health risks:

- Noncarcinogenic hazard quotient (HQ) for each detected chemical and the cumulative hazard index (HI) for all chemicals detected in the subslab sample based on EPA Region 3 toxicity values (EPA 2009b)[4]; and
- Carcinogenic risk for each chemical and the cumulative carcinogenic risk for all chemicals detected in the subslab sample risk based on EPA Region 3 toxicity values.

The methods used to develop the vapor intrusion sampling design and calculate human health risks are presented in:

- U.S. EPA's *Risk Assessment Guidance for Superfund, Volume I, Part A* (RAGS; EPA 1989);
- *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (Subsurface Vapor Intrusion Guidance) (EPA Region 6 2002); and
- *United States Environmental Protection Agency, Region 3, Hazardous Site Cleanup Division, Vapor Intrusion Framework* June 2009

U.S. EPA risk assessment guidance and policies (EPA 1989[3], 2002[1]) require that individual chemical risks be calculated for each detected chemical and that those risks be summed when an individual is exposed simultaneously to multiple chemicals in order to derive the cumulative risk. Health risks must be calculated for the "reasonable maximum exposed" (RME) individual, which forms the basis for making a risk management decision according to U.S. EPA's risk management framework (EPA 1992). It should be stressed that one of the most important assumptions in the RME scenario for calculating cancer risk is that the exposed individual will be exposed for numerous years.

A human health risk assessment is conducted in a stepwise manner with the following 4 steps:

- Data Assessment;
- Exposure Assessment;
- Toxicity Assessment; and
- Risk Characterization.

The following sections briefly describe each of these four analyses.

2.1 DATA ASSESSMENT

Vapor intrusion is the pathway through which Riggs Park residents are potentially exposed to ground water contamination. This conceptual site model is consistent with the model presented in U.S. EPA's *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (EPA Region 6 Guidance; EPA 2002), which supplements RAGS. The first step in the data assessment is to identify the best representative sampling data to calculate the chemical dose associated with exposure following vapor intrusion into the home. Many different types of samples were collected by SSP&A (2008) to characterize the nature and extent of contamination in the Riggs Park community. While each different type of sample provides valuable site-characterization information, only sub-slab vapor monitoring port (VMP) samples provide information and data directly linking contaminated ground water to vapor intrusion into homes. For this reason, health risks and hazards calculated in this HHRA are based solely on VMP samples. This approach is based on EPA guidance (EPA 2002) which states: "Sampling of foundation air (e.g., sub-slab and/or crawlspace air) provides a direct measure of the potential for exposures from vapor intrusion."[5] While other types of samples (like indoor air samples collected from inside the home) can be used in risk assessments, numerous analytical steps must be carried out to eliminate confounding "extraneous" chemicals that are not associated with contaminated groundwater from the sampling and analysis result. For example, outdoor air samples usually contain ambient or background vapor sources, while chemical vapors from household products are usually detected in indoor air samples. Attempts to eliminate these extraneous sources with analytical or statistical approaches can introduce considerable (and unacceptable) uncertainty into the HHRA.

Basement concrete slabs and foundation walls govern intrusion of vapors into homes. Sub-slab vapors can only enter homes by migrating upward through cracks and openings (i.e., holes for electrical utilities, sumps, etc.) in the concrete. The ability of the concrete slab to prevent vapor intrusion is termed vapor "attenuation" and the magnitude of attenuation is represented by an attenuation factor (AF). In quantitative terms, the AF is the ratio between the concentration detected in an indoor air sample and the corresponding VMP sample as represented by α_{sg} in the following equation:

$$\mathbf{AF = \alpha_{sg} = Concentration\ indoor\ air/Concentration\ sub\text{-}slab\ soil\ gas}$$

EPA guidance (EPA 2002) recommends using an attenuation factor of 0.1 for sub-slab soil gas samples that are collected just beneath the concrete slab. Although some scientists consider this default value too conservative, a recent re-evaluation by EPA has confirmed it is both reasonable and applicable for most sites based on a detailed analysis of empirical data. The most recent EPA guidance (EPA 2009a) states:

> "Appendix F of the 2002 HQ Guidance presents a review of groundwater, soil gas, sub-slab and indoor air data from fifteen vapor intrusion sites nationwide and, based on an evaluation of the data, makes recommendations for "default" generic attenuation factors (except under certain conditions as noted in the Guidance). For example, Appendix F recommends a default attenuation factor of 0.1 (i.e., 1/10) be used to predict indoor air concentrations from vapors migrating from the sub-slab. This value is for the upper bound statistical measure, the 95th percentile."

It is important to note that, while an AF of 0.1 may not represent current conditions, EPA guidance requires that all remedial decisions consider both current and future site conditions and associated potential risks. For example, RAGS specifically requires risks to be calculated at all hazardous waste sites under current and hypothetical future exposure conditions. Despite the fact that current conditions may not pose unacceptable human health risks, U.S. EPA requires site remediation be based on the potential for vapor intrusion to pose unacceptable risks in the future. Put another way, it is U.S. EPA's policy to remediate chemicals when the <u>potential</u> for elevated health risk exists. EPA's most recent guidance (EPA 2009a) states:

> "Risk managers would be justifying a decision to take mitigative action based on an acceptance of the attenuation factor approach and the potential for indoor air values to reach unacceptable levels. In theory, risk managers could justify mitigation even if a one- or two-time indoor air sampling event revealed results below levels of concern since the manager would be relying on the predictive capability of the attenuation factor and a belief that, over time, deteriorating foundation conditions can only lead to greater opportunity for vapors to enter the home."[2]

This concept was applied to the HHRA conducted for Riggs Park homes. While an AF may currently overestimate vapor intrusion for *all* homes, it will likely be applicable to some homes in the future as the concrete slab deteriorates.

In this risk assessment, the AF was applied in the first step of data assessment by multiplying the concentration detected in the VMP sample for each chemical by 0.1. For example, if the concentration detected in a VMP sample was 25 ug/m^3 for a particular chemical, the exposure point concentration representing the indoor air concentration for that chemical would be 2.5 ug/m^3.

The results of this HHRA were based on 357 vapor monitoring port VMP samples that were collected from 106 Riggs Park homes. In total, several thousand cumulative health risk analyses were performed on each of the VMP samples. EPA Method TO-15 was used to analyze all samples, which is the method of choice in vapor intrusion studies. With this method, sixty-six chemicals were analyzed at very low detection limits. For the 106 Riggs Park homes for which there were VMP samples, 37 of the 66 analytes were identified as "chemicals of interest" (COI). These were defined as chemicals detected in VMP samples in at least five different homes. A list of these COIs is presented in Exhibit 1.

EXHIBIT 1
CHEMICALS OF INTEREST DETECTED IN VMP SAMPLES

CHEMICALS OF INTEREST
1,1,1-Trichloroethane
1,1-Dichloroethene
1,2,4-Trichlorobenzene
1,2,4-Trimethylbenzene
1,2-Dichlorobenzene
1,3,5-Trimethylbenzene
1,3-Dichlorobenzene
2-Butanone (MEK)
Acetone
Chlorobenzene
Chloromethane
cis-1,2-Dichloroethene
Cyclohexane
Ethyl acetate
Ethylbenzene
Hexane
Naphthalene
Styrene
Toluene
trans-1,2-Dichloroethene
Xylenes
1,2-Dichloroethane
1,3-Butadiene
1,4-Dichlorobenzene
1,4-Dioxane
Benzene
Carbon tetrachloride
Chloroethane
Chloroform
Hexachlorobutadiene
Methyl tert-butyl ether
Methylene chloride
Tetrachloroethene
Tetrahydrofuran
trans-1,3-Dichloropropene
Trichloroethene
Vinyl chloride

Some vapor intrusion studies follow a "groundwater up" approach in which the COIs are selected *a priori* rather than identified based on site-specific empirical data. That is, rather than identifying COIs based on a detailed analytical review of chemicals actually detected in VMP samples, groundwater up analyses are predicated on a presumption of the type of contaminants that should be detected in groundwater. At sites where all groundwater contaminants have been comprehensively analyzed and the groundwater has been fully characterized, the groundwater up approach is appropriate. However, for sites where groundwater analyses are limited and groundwater contamination is not well characterized, it is not appropriate to apply a groundwater up approach. Rather, it is prudent to apply a VMP down approach where all COIs are first identified in VMP samples. This is followed by a further source analysis investigation to confirm the COIs detected in VMP samples are also detected in groundwater.

Groundwater analyses in the Riggs Park subdivision have been, for the most part, limited to gasoline constituents. Residents have expressed concerns that groundwater has not been fully characterized and previous investigations may have ignored contaminants. The VMP down approach was selected as the most appropriate because it ensured that nothing was overlooked, it followed the recommendations presented in RAGS, and it addressed the concerns expressed by the residents. With this approach, uncertainty about COIs being unknowingly ignored or incorrectly omitted from the HHRA is eliminated.

After identifying the initial list of COIs for the entire VMP database representing Riggs Park homes, the cancer risk and noncancer hazard quotient were calculated for each COI in each VMP sample. Contaminants posing a cancer risk $\geq 1\text{x}10^{-5}$ or a hazard index ≥ 1.0 based on the detected concentration in a VMP sample (after applying an AF of 0.1) were subsequently identified as chemicals of concern. Exhibit 2 presents the list of COCs.

EXHIBIT 2
CHEMICALS OF CONCERN DETECTED IN VMP SAMPLES

CHEMICALS OF CONCERN
1,4-Dichlorobenzene
Carbon tetrachloride
Chloroform
Methylene chloride
Naphthalene
Tetrachloroethene

2.2 EXPOSURE ASSESSMENT

In the second step of this HHRA, the chemical dose was calculated for each chemical detected in a VMP sample according to EPA risk assessment guidance (EPA 1989; 2002), which is referred to as the chronic daily intake or chronic daily inhalation dose (CDI). To calculate the noncarcinogenic CDI, variables such as the frequency and duration of exposure are combined with the exposure point concentration (AF multiplied by the VMP concentration), which is then averaged over the total time of exposure. Exhibit 3 presents the exposure assumptions used to calculate the CDI for both carcinogens and noncarcinogens.

EXHIBIT 3
EXPOSURE PARAMETERS[4]

Chronic Daily Inhalation Dose (CDI) =(C x EF x ED)/(AT x CF)	
Variable	**Input Value**
C = Chemical concentration ($\mu g/m^3$)	VMP Conc. x 0.1
EF = Exposure frequency (days/year)	350
ED = Exposure duration (years)	30
CF = Conversion factor	1000 µg/mg
AT = Averaging time (days)	
Noncarcinogenic	10,950
Carcinogenic	25,550

Note: The CDI is based on the assumption that exposure is for an adult with a 70 kg body weight.

2.3 TOXICITY ASSESSMENT

Toxicity values represent the inherent toxicity of chemicals and provide the dose-response information necessary for quantifying cancer risk and the noncancer HQ. Each toxicity value expresses the mathematical relationship between the dose and the most sensitive (occurring at the lowest dose) toxic response. For vapor inhalation exposures, the Inhalation Unit Risk (IUR) and the inhalation reference concentration (RfC) are the preferred toxicity values used to calculate the chemical-specific cancer risk and noncancer HI, respectively.

The toxicity values adopted by EPA Region 3 in September 2008 were used to calculate cancer risk and noncancer HI for all 37 COI in this HHRA. Those toxicity values are presented in Exhibit 4.

EXHIBIT 4
SUMMARY OF TOXICITY VALUES FOR 37CHEMICALS OF INTEREST

Chemicals of Interest	IUR $(\mu g/m^3)^{-1}$	RfC (mg/m^3)
1,1,1-Trichloroethane	NA	5.0
1,1-Dichloroethene	NA	2.0E-01
1,2,4-Trichlorobenzene	NA	4.0E-03
1,2,4-Trimethylbenzene	NA	7.0E-03
1,2-Dichlorobenzene	NA	2.0E-01
1,2-Dichloroethane	2.6E-05	2.4
1,3,5-Trimethylbenzene	NA	6.0E-03
1,3-Butadiene	3.0E-05	2.0E-03
1,3-Dichlorobenzene	NA	NA
1,4-Dichlorobenzene	1.1E-05	8.0E-01
1,4-Dioxane	7.7E-06	3.6
2-Butanone (MEK)	NA	5.0
Acetone	NA	3.1E+01
Benzene	7.8E-06	3.0E-02
Carbon tetrachloride	1.5E-05	1.9E-01
Chlorobenzene	NA	5.0E-02
Chloroethane	NA	1.0E+01
Chloroform	2.3E-05	9.8E-02
Chloromethane	NA	9.0E-02
cis-1,2-Dichloroethene	NA	NA
Cyclohexane	NA	NA
Ethyl acetate	NA	NA
Ethylbenzene	2.5E-06	1.0
Hexachlorobutadiene	7.8E-02	2.2E-05
Hexane	NA	7.0E-01
m,p,o-Xylene	NA	7.0E-01
Methyl tert-butyl ether	2.6E-07	3.0
Methylene chloride	4.7E-07	1.0
Naphthalene	3.4E-05	3.0E-03

Chemicals of Interest	IUR $(\mu g/m^3)^{-1}$	RfC (mg/m^3)
Styrene	NA	1.0E
Tetrachloroethene	5.9E-06	2.7E-01
Tetrahydrofuran	NA	NA
Toluene	NA	5.0
trans-1,2-Dichloroethene	NA	6.0E-02
trans-1,3-Dichloropropene	NA	NA
Trichloroethene	2.0E-06	NA
Vinyl chloride	4.4E-06	1.0E-01

NA: Not Available
Note: 5.9E-06 is another way to express $5.9x10^{-6}$. The terms are interchangeable.

2.4 RISK CHARACTERIZATION

In the last step of HHRA, the cancer risk and noncancer hazard index are calculated for each COI detected in a VMP sample. In this step, the CDI is combined with the toxicity value.

Cancer risk is calculated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen. It is presented as the "excess individual lifetime cancer risk" (ELCR) as expressed in the following equation:

ELCR = CDI x IUR

Where:

ELCR = A unitless probability of an individual developing cancer over a 70-year lifetime associated with inhaling a cancer-causing chemical in their home.

CDI = Chronic daily inhalation dose of the chemical averaged over 30 years (mg/kg-day).

IUR = Inhalation unit risk $(ug/m^3)^{-1}$.

The ELCR is calculated for each COI detected in the VMP sample. The cumulative ELCR for the sample is then calculated by summing all the chemical-specific ELCRs calculated for the sample. Risk management decisions were based on the VMP sample with the highest calculated ELCR.

Unlike the ELCR for cancer risk, noncarcinogenic health hazards are not represented as a probability. Instead, the HI represents the ratio of the CDI to the inhalation reference concentration. The RfC is the EPA-derived toxicity value that represents the average daily exposure concentration that is deemed "safe or acceptable." That is, a person in good health continuously inhaling a chemical corresponding to an RfC level would not be expected to experience any untoward or toxic effects. The ratio of the CDI and the RfC is termed the "hazard quotient" and is calculated as follows:

Hazard Quotient (HQ) = CDI/RfC

Where:

HQ = The safe or acceptable concentration for a particular chemical.

CDI = Chronic daily inhalation dose of the chemical averaged over 30 years (mg/kg-day).

RfC = Reference concentration (ug/m^3).

The HQ is calculated for each detected chemical in a VMP sample. The cumulative noncancer health hazard is represented by the hazard index (HI) and it is derived by summing the chemical-specific HQs for each COI in the VMP sample.

3.0 RISK MANAGEMENT

The EPA risk management framework is presented in the National Contingency Plan (NCP)[6]. For cumulative cancer risk, a $1x10^{-6}$ ELCR level is defined as the *"de minimus"* risk level below which risks are considered insignificant. The ELCR range of $1x10^{-6}$ to $1x10^{-4}$ is defined as EPA's discretionary risk range.[7] Ultimately, EPA sets an acceptable level by first evaluating whether the calculated health risks could have been over- or underestimated, by analyzing site-specific conditions. Based on the outcome of these analyses, the Agency uses its discretion to establish a specific ELCR as the "acceptable risk level." It should be stressed that the analysis EPA conducts to set an "acceptable" risk level is qualitative; EPA does not carry out any quantitative analyses. This process is termed "risk management."

Setting the acceptable HI level for noncancer health effects is much more straightforward than setting the acceptable cancer risk. Since, by definition, the HI represents the ratio between the exposed dose (CDI) and the safe dose, the acceptable HI is set at 1.0. For example, when the measured concentration of a particular chemical in a home is equal to the safe concentration, no adverse health effects would be expected to occur in that home. In this situation, the chronic daily intake would equal the acceptable exposure level, and the CDI/RfC ratio would be 1.0.

Although an HI of 1.0 is generally considered health protective of the general population, it may not be protective for some "sensitive" individuals. This is because the toxicity values used to calculate risks are based on studies of healthy populations of either laboratory animals or humans. That is, most toxicology studies are designed to study the effects of chemicals on mature test subjects that do not have pre-existing medical conditions. In some instances, applying EPA-derived toxicity values to populations with pre-existing medical conditions may underestimate risks. For example, an individual with preexisting liver disease may be predisposed to toxic contaminants that also target the liver. Anecdotal information suggests that some Riggs Park residents may have pre-existing medical conditions. Riggs Park residents also include the elderly and children who may be especially sensitive to some toxicants. However, since medical information and records were not available for Riggs Park residents, it was not possible to apply any additional safety factors in this HHRA.

EPA Region 3 has set the acceptable cancer ELCR level for Riggs Park at 1×10^{-5}. After evaluating site-specific conditions and other factors, it was concluded that it is prudent for DDOE to follow suit. As previously discussed, all health risks in this report were calculated based on the detectable concentrations of contaminants in VMP samples. Accordingly, the magnitude of the VMP-based risk was the central focus for managing those risks. Although the determination of whether remediation is warranted should be risk-based, effective risk mitigation requires that a groundwater contaminant source be present. That is, it is necessary but not sufficient to target a particular home where the calculated risks exceed the ELCR benchmark. For VMP installation to be warranted and be effective in exhausting vapors in the subslab space before they can migrate through cracks in the concrete slab, it must be demonstrated that a contaminated groundwater source is present under or near the home. For homes where VMP samples were not collected, the final risk management determination is based on a "weight-of-evidence" (WOE) approach.

Where VMP data was available, the risk management decision-making process is presented in Exhibit 5. This flow chart shows the detailed step-by-step analysis that was conducted including the analytical steps conducted, pivotal points where decisions were made, and the criteria for making those decisions. This approach is termed Risk Management Framework A (RM Framework A).

It was necessary to develop an alternative risk management WOE approach for a small subset of homes where no VMP data was available. This alternative risk management paradigm is termed Risk Management Framework B (RM Framework B) and the steps of this process are presented in Exhibit 6. A narrative description of both exhibit 5 and exhibit 6 is presented in sections 3.1 and 3.2, respectively.

EXHIBIT 5 RISK ASSESSMENT AND MANAGEMENT APPROACH A: HOMES WITH VMP DATA

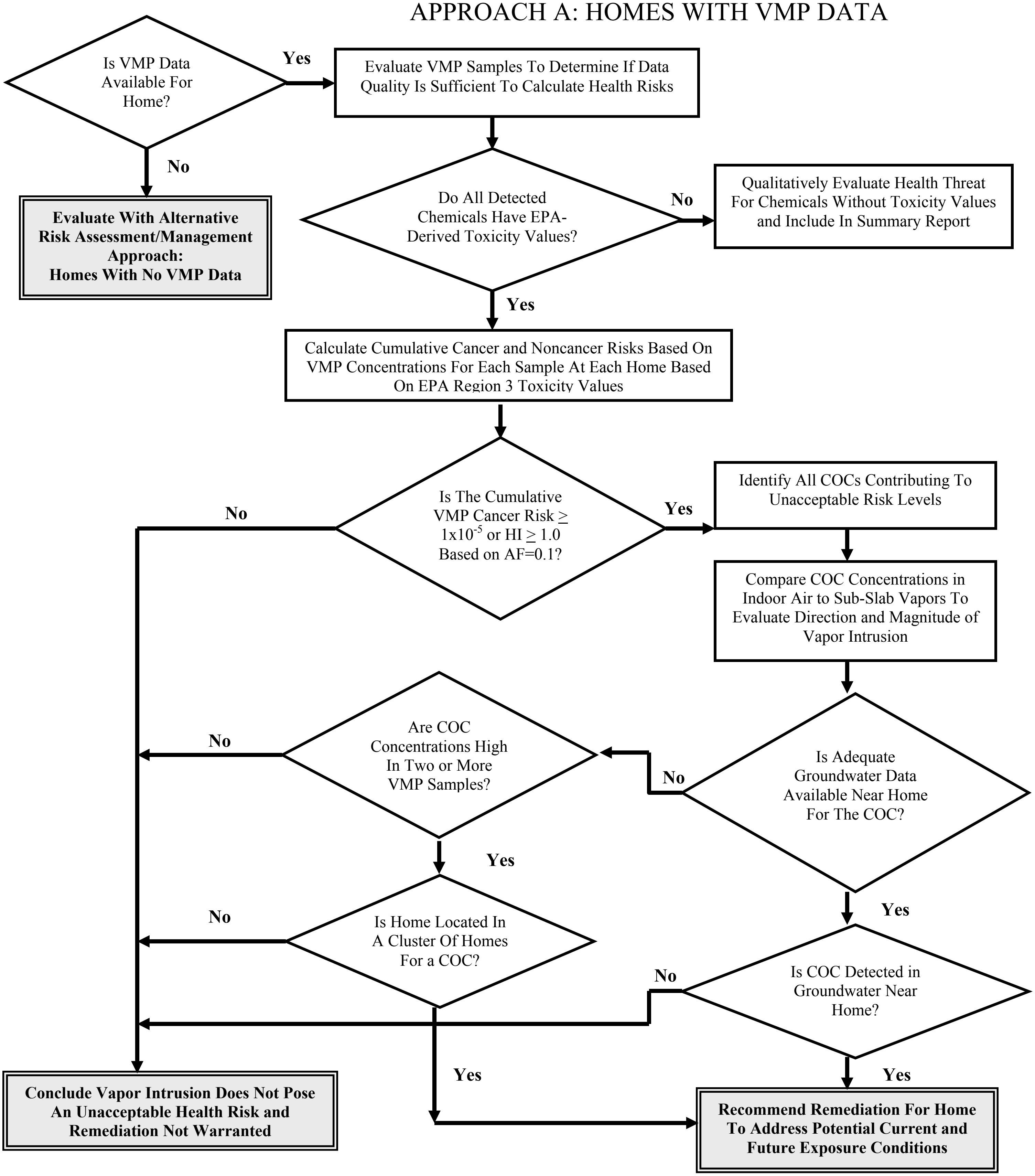
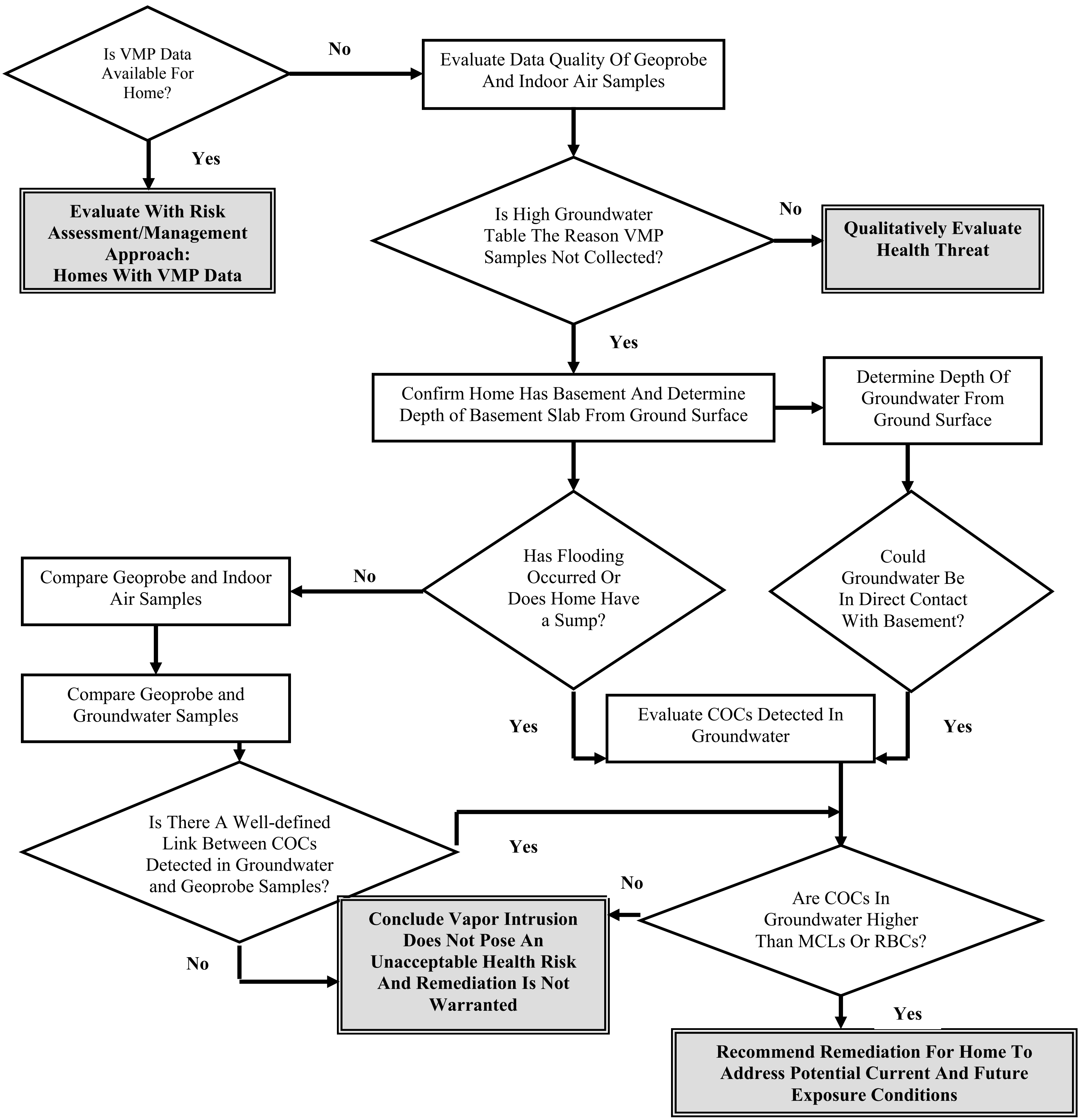


EXHIBIT 6 RISK ASSESSMENT AND MANAGEMENT
APPROACH B: SAMPLED HOMES WITH NO VMP DATA



3.1 OVERVIEW OF RM FRAMEWORK A

The first step in RM Framework A is to confirm that at least one VMP sample was collected for each Riggs Park home (it was confirmed that at least one VMP sample was collected for all but 12 homes included in this investigation). For homes with VMP samples, a comprehensive assessment of data quality was conducted to determine if the sampling results are of sufficient quality to be used in this HHRA. This assessment involved reviewing all pertinent data quality parameters such as detection limits, data qualifiers, and whether duplicate sampling results were comparable. Overall, VMP samples were determined to be of high quality and satisfied the criteria necessary for quantifying human health risks. Furthermore, based on the very low detection limits, it was unlikely that any chemicals went undetected and, therefore, it is unlikely that health risks were underestimated due to sampling and analysis problems.

For each VMP, each COI was evaluated to determine if an EPA-derived toxicity value was available to quantify risks. The relatively few chemicals that have no EPA-derived toxicity values were qualitatively evaluated.

The cumulative ELCR and noncancer health index were calculated for all COIs detected in each VMP sample. All homes where the ELCR > 1×10^{-5} or the HI > 1.0 were advanced to the analysis. Homes with cancer risks and noncancer HIs less than these benchmarks were not further evaluated. To address the question of whether the COCs detected in the VMP samples could be due to downward migration from inside the home into the sub-slab vapor space, the concentration detected in the VMP sample was compared with the corresponding indoor air sample (to be thorough, this analysis was performed on all COIs detected in the VMP sample in addition to those COCs that posed unacceptable risk). Based on an AF value of 0.1 that was used as the default for all Riggs homes, the concentration in the indoor air sample would need to be 10 times the concentration detected in the VMP sample (the AF applies to both downward and upward vapor intrusion). This evaluation revealed that the hypothesized downward migration was not occurring at any home investigated for this report. Based on this thorough analysis, it was confirmed that all COCs detected in VMP samples above acceptable health based levels were directly linked to a sub-slab vapor source.

The second major risk management criterion in RM Approach A is to confirm the COC posing unacceptable risk is linked to groundwater. This criterion was necessary to ensure a continuous chemical source was present since cancer risk is predicated on the assumption of chronic exposure to carcinogens (i.e. a transient or short exposure period is not sufficient to produce cancer). The groundwater investigation was limited to the existing groundwater dataset generated by Chevron, which was collected during the same year when VMP samples were collected. Although numerous data gaps were identified in the dataset, an alternative groundwater dataset does not exist. The dataset is insufficient both in regard to the number of VOCs analyzed and the elevated detection limits for numerous VOC that were analyzed. This means that some contaminants may have been present but (unknowingly) have gone undetected.

At Riggs Park homes where the VMP health risks were unacceptable but the groundwater dataset was insufficient to confirm a groundwater source (as described above), additional analyses were conducted to determine if there was a pattern of high concentrations corresponding to unacceptable health risks in other VMP samples. For those homes where unacceptable risk was calculated for more than one VMP sample, a spatial analysis was conducted of homes where the same COC was detected in VMP samples above acceptable levels but where no groundwater data was available.

In the final step of RM Framework A, mitigation is recommended for Riggs Park homes that satisfy two criteria. The first criterion is that a COC must be detected in a VMP sample at an unacceptable risk level. The second criteria is that, for that same home, there either must be a confirmed link between the VMP sample and groundwater (contaminated with the same COC) or the home must be part of a cluster of homes where the VMP samples show unacceptable levels for the same COC.

3.2 OVERVIEW OF RM FRAMEWORK B

Twelve homes without VMP samples were also included in this investigation. Sub-slab vapor samples were not collected either because the homeowner did not grant sampling access or the water table was too high and subslab soils were saturated. For these homes, it was necessary to develop an alternative risk management framework that did not depend on VMP sampling results to determine whether remediation is warranted.

In the absence of VMP samples, it was necessary in the first step to evaluate geoprobe and indoor air samples. For those homes in this group for which VMP samples were not collected because the resident would not grant access, a qualitative analysis was conducted. For the remaining homes, an evaluation of the home was conducted to determine the depth of the basement slab relative to the groundwater depth. This is an important consideration because if groundwater is in direct contact with the basement and that groundwater is contaminated, the potential for vapor intrusion is enhanced. For those homes with groundwater in direct contact with the either the basement foundation wall or basement slab, groundwater results were analyzed. Where the water table was slightly lower and there was no evidence of direct groundwater contact the inspection summary reports were reviewed to determine if the home had a sump or whether the basement floods as these conditions would also enhance vapor migration. A groundwater evaluation was conducted for homes that were in direct contact with groundwater, experienced flooding, or had a sump. Following EPA guidance (EPA 2002), if the groundwater concentration of any volatile chemicals at these homes exceeded a maximum contaminant level (MCL) or risk-based concentration (RBC), the home was recommended for remediation. MCLs and RBCs are risk-based concentrations that have been derived by the Agency and represent safe levels of contaminants in drinking water. EPA has extended the use of these safe drinking water levels to vapor intrusion studies. That is, if the chemical concentration for VOCs in groundwater is found to be less than MCLs or RBCs, EPA has concluded they should not pose a risk or threat to human health. For homes not in contact with groundwater, that did not flood, or that did not have a sump, geoprobe samples were compared with indoor air samples and groundwater samples. Where a link could be confirmed between the geoprobe sample and groundwater contamination, and the COC was detected in groundwater above the MCL, the home was identified as a home requiring remediation.

4.0 RESULTS

Calculating health risks is the most important step in vapor intrusion studies. In this HHRA, the ELCR and noncancer HQ were calculated for each COI detected in each VMP sample collected for each participating Riggs Park home to identify the COC(s) of primary concern for that home. In addition, the cumulative ELCR and HI were calculated to determine the health risks associated with simultaneous exposure to all vapors that have the potential to migrate into the home. While risk information is vital for making informed and transparent risk management decisions, many more analyses are ultimately necessary to justify taking remedial action. It is equally important to conduct a comprehensive analysis for homes not targeted for remediation so that the homeowner can be assured that the risk management decision is sound and based on a thorough evaluation of all site conditions.

For the sake of brevity, the comprehensive summary results for all analyses conducted for each Riggs Park home investigated in this HHRA have been tabulated. These home-specific results are presented in Appendix A. To facilitate direct comparisons and ensure the risk management criteria discussed in the previous section were equally applied to all homes in this HHRA, the summary data is presented in the same format

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the analytical results described in the previous section, and applying one of the two risk management frameworks, it was concluded that remediation is warranted for 43 Riggs Park homes. Nineteen homes require remediation because unacceptable concentrations of PCE were detected in sub-slab vapor samples. Remediation is also warranted for an additional 8 homes that were located within an area bounded by a kriging analysis and 12 homes that shared a common basement slab with homes targeted for remediation. Lastly, 3 homes require remediation due to unacceptable chloroform concentrations detected in sub-slab vapor samples and 1 home was in direct contact with contaminated groundwater.

Sampling and analysis results show that 22 homes warrant remediation due to contaminant levels measured directly in the sub-slab vapor space under the home. However, not all Riggs Park homes were sampled for this investigation. Although many homeowners chose not to participate in this study, important site-specific results gathered as part of this study must be applied to all homes in the Riggs Park neighborhood to ensure protection of public health for all residents. For this reason, two additional analyses were conducted, extending the findings in this study to neighboring or surrounding homes. The first analysis was conducted to determine whether the adjoining duplexes of each of the 22 homes that were targeted for remediation were included in the study. This is important since the adjoining duplex (not sampled) would be located over the same contaminated groundwater plume as the home identified as needing remediation. Since they would share the same basement concrete slab, it is reasonable to assume the sub-slab vapor contaminant conditions would be very similar. In this analysis, all available information on the adjoining duplex was evaluated and, if VMP samples were collected and the ELCR for that home was calculated to be acceptable, it was not included in the list of homes requiring remediation. Where the adjacent duplex home was sampled and found to have unacceptable VMP risks, it was included as another home requiring remediation. For those adjacent duplex homes that did not participate in this study and were not sampled, they were identified as homes requiring remediation as a prudent public health measure. 12 homes were recommended for remediation based on this evaluation.

In the second analysis, the modeling procedure of kriging was performed to determine if remediation was warranted for any other surrounding homes in the area (in addition to the physically attached duplex home previously discussed). As in the previous analysis, this analysis was conducted as a prudent measure to fill an existing data and information gap. If the kriging results showed other surrounding homes should be included as a “cluster” of homes, these were also included. Eight homes were recommended for remediation based on this evaluation.

Finally, for the 12 homes where GMP samples but VMP samples-were collected, it was determined that only one home warrants remediation due to petroleum and chloroform contamination in groundwater above acceptable levels.

After concluding all presented analyses, it has been determined that a total of 43 homes warrant remediation. These homes are listed in Exhibit 7 along with the rationale for taking remedial action.

EXHIBIT 7
SUMMARY TABLE OF RIGGS PARK HOMES REQUIRING REMEDIATION

Home ID	Rationale
S13	PCE VMP Risk
S30	PCE VMP Risk
S33	PCE VMP Risk
S36	PCE VMP Risk
S37	PCE VMP Risk
S88	PCE VMP Risk
S96	PCE VMP Risk
S107	PCE VMP Risk
S121	PCE VMP Risk
S143	PCE VMP Risk
S194	PCE VMP Risk
S199	PCE VMP Risk
S239	PCE VMP Risk
S257	PCE VMP Risk
S258	PCE VMP Risk
S322	PCE VMP Risk
S362	PCE VMP Risk
S416	PCE VMP Risk
S419	PCE VMP Risk
S32	Home in Area of Extrapolated PCE Risk
S195	Home in Area of Extrapolated PCE Risk
S196	Home in Area of Extrapolated PCE Risk
S260	Home in Area of Extrapolated PCE Risk
S310	Home in Area of Extrapolated PCE Risk
S363	Home in Area of Extrapolated PCE Risk
S366	Home in Area of Extrapolated PCE Risk
S418	Home in Area of Extrapolated PCE Risk
S11	Duplex of Home S13
S20	Duplex of Home S121
S89	Duplex of Home S362
S100	Duplex of Home S287
S106	Duplex of Home S107

Home ID	Rationale
S157	Duplex of Home S96
S324	Duplex of Home S322
S35	Duplex Home of S33 & Home in Area of Extrapolated PCE Risk
S162	Duplex Home of S239 & Area of Extrapolated PCE Risk
S309	Duplex of Home S143 & Area of Extrapolated PCE Risk
S369	Duplex Home of S199 & Home in Area of Extrapolated PCE Risk
S420	Duplex Home of S37 & Home in Area of Extrapolated PCE Risk
S296	Chloroform VMP Risk
S287	Chloroform VMP Risk
S354	Chloroform VMP Risk
S167	Home With No VMP Samples, based on GMP and groundwater results. Petroleum, Chloroform

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[1] EPA 2002. OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance). November 2002 EPA530-D-02-004

[2]United States Environmental Protection Agency, Region 3, Hazardous Site Cleanup Division, Vapor Intrusion Framework June 2009 EPA 2009a.

[3] EPA 1989. Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A), Interim Final. December 1989.

[4] EPA 2009b. EPA Region 3 Toxicity Values. Tabulated in: http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm

[5] *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils* (Subsurface Vapor Intrusion Guidance) (EPA Region 6 2002);

[6] 1990 National Contingency Plan (NCP) (55 Fed. Reg. 8665-8865 (Mar. 8, 1990))

[7] EPA 1991. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions ("Don Clay Memo"). APR 22 1991. OSWER Directive 9355.0-30