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BROADBENT & ASSOCIATES, INC.
ENGINEERING, WATER RESOURCES & ENVIRONMENTAL

December 30, 2009 Project No. 95-01-150

Ms. Sara Arav-Piper
Nevada Division of Environmental Protection, Bureau of Corrective Actions
2030 E. Flamingo Road, Suite 230
Las Vegas, Nevada 89119

Re: Human Health Risk Assessment Update, Avis/National/Payless Commingled Groundwater Plume, Las Vegas, Nevada

Dear Ms. Arav-Piper:

Please find attached the *Human Health Risk Assessment Update* (December 2009 Update) for the Avis/National/Payless commingled groundwater plume in Las Vegas, Nevada. As requested in a letter dated September 21, 2009 from the Nevada Division of Environmental Protection, changes were made to this human health risk assessment (HHRA) from the August 2009 edition. These changes include the addition of tertiary butyl alcohol (TBA) into the HHRA and also the addition of a comparison of site-specific soil parameters to worst-case (i.e., sand) soil parameters for the vapor intrusion modeling process.

If you have any questions or if you need any additional information, please do not hesitate to contact our office at (702) 563-0600.

Sincerely,
BROADBENT & ASSOCIATES, INC.

Jason Hoffman, CEM #1904 (expires 1/26/11)
Project Geologist

JURAT: I, Jason Hoffman, hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and to the best of my knowledge comply with all applicable federal, state, and local statutes, regulations, and ordinances.

cc: Ms. Rose Pelino, Avis Budget Group, Inc., 6 Sylvan Way, Parsippany, New Jersey 07054
Mr. Bob Schultz, AMEC/Geomatrix Consultants, Inc., 2101 Webster Street, 12th Floor, Oakland, California, 94612
Ms. Sydney Elkins – McCarran International Airport, Environmental Quality, P.O. Box 11005, Las Vegas, Nevada, 89111
Mr. Robert Gegenheimer, Converse Consultants, 731 Pilot Road, Suite H, Las Vegas, Nevada, 89119-4429
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HUMAN HEALTH
RISK ASSESSMENT UPDATE

AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME
Las Vegas, Nevada

December 2009 Update

Prepared by:

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Boerne, Texas

Prepared for:

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ACRONYMS AND ABBREVIATIONS

atm-m^3/mol	Atmospheres per cubic meter per mole
ATSDR	Agency for Toxic Substances and Disease Registry
BAI	Broadbent and Associates, Inc.
bgs	Below ground surface
BTEX	benzene, toluene, ethylbenzene and total xylenes
cm^2	square centimeters
CNS	Central nervous system
COPC	Chemical of potential concern
CSF	Cancer slope factor
CT	Central tendency
days/year	Days per year
EPA	U.S. Environmental Protection Agency
EPC	Exposure point concentration
g/mol	Gram per mole
HHRA	Human health risk assessment
HI	Hazard index
hr/day	Hour per day
HQ	Hazard quotient
IR	Ingestion rate
IRIS	Integrated Risk Information System
kg	Kilogram
L/m^3	Liter per cubic meter
MCL	Maximum contaminant level
mD	Millidarcies
m^3/day	Cubic meter per day
mg/kg-day	Milligram per kilogram per day
mg/m^3	Milligram per cubic meter
MTBE	Methyl tert-butyl ether
NCEA	National Center for Environmental Assessment
NCP	National Contingency Plan
NOAEL	No observed adverse effect level
PPRTV	Provisional peer-reviewed toxicity values
PRG	Preliminary remediation goal
RAGS	Risk Assessment Guidance for Superfund
RfC	Reference concentration
RfD	Reference dose
RME	Reasonable maximum exposure
TBA	Tert-butyl alcohol
TPHCWG	Total Petroleum Hydrocarbon Criteria Working Group
TPH-Gas	Total petroleum hydrocarbons – gasoline range
µg/m^3	Microgram per cubic meter
URF	Unit risk factor
VOC	Volatile organic compound

1.0 INTRODUCTION

Broadbent & Associates, Inc. (BAI) authorized Synergy Toxicology to perform an update of the human health risk assessment (HHRA) on the Avis / National / Payless commingled groundwater plume area (the Site) located in Las Vegas, Nevada. This human health risk assessment is an update of a screening-level HHRA completed by Synergy Toxicology in July 2008 (the July 2008 HHRA was an update of a 2000 HHRA by J.G. Van de Water and T.L. Copeland). The updated HHRA is based on a review of existing reports and data regarding the Site, which is located just east of McCarran / Las Vegas International Airport (see Figure 1). The update is needed since soil gas data have been collected in 2009. Soil gas data are more descriptive of subsurface conditions relative to the vapor intrusion pathway and can reduce uncertainty in risk estimates developed using groundwater-to-air modeling, such as the 2008 HHRA. The groundwater plume in question underlies an area currently used for commercial (e.g., automobile rental outlets and a hotel) and residential purposes, which are also the likely future land uses in the immediate area of the plume. Details of the data collection and site investigation activities to date are summarized elsewhere (BAI 2007, 2008, 2009).

The purpose of the updated HHRA is to characterize the potential human health risks associated with exposure to site-related chemicals under current and future land use conditions, without regard to future remedial activities or any attempt to control or mitigate chemical release(s). The information in this HHRA may be used to select appropriate remedial alternatives for the Site, if necessary. As the properties above the plume are developed with commercial and residential structures, exposure assumptions are applicable for assessment of risks to current and future receptors. The businesses and residents in the vicinity of the plume are connected to the public water supply and shallow groundwater use for drinking, irrigation, or other purposes is highly unlikely. While the State of Nevada considers all groundwater to be a potential future drinking water source, the primary drinking water standards (in this case, Maximum Contaminant Levels [MCL]) are not likely to be enforced as high TDS in shallow Las Vegas groundwater precludes its use as a drinking water aquifer. For this reason, risks based on pathways other than the drinking water pathway are under consideration.

The site-specific HHRA for the Site was completed in general accordance with the methods detailed in Parts A through E of the U.S. Environmental Protection Agency's (EPA) *Risk Assessment Guidance for Superfund* (RAGS). Appendix A presents the EPA-recommended RAGS-style tables (see Table A-1 through A-7). Appendix B presents subsurface information from the soil gas well installations, and Appendix C presents the model input and output used in estimating cross-media concentrations (i.e., soil gas to indoor air).

1.1 Data Evaluation

The objectives of the data evaluation process were to 1) review and summarize the analytical data in the areas potentially impacted by the migration of groundwater contaminants at the Site and 2) identify groundwater COPCs for evaluation in the HHRA. Analytical summary statistics used to perform the HHRA for the Site are provided in the RAGS-recommended tables of Appendix A (see Table A-2.1 and A-2.2).

The screening level HHRA completed in 2000 (Van de Water and Copeland 2000) included groundwater monitoring data through June 2000. Groundwater data used in the 2008 HHRA update (Synergy Toxicology 2008) were collected between July 2000 and March 2008. Analytical data used in this update are from soil gas collected from four locations across the plume at depths of five and eight feet below ground surface (see Table 1).

Because soil gas data collected at shallower depths than groundwater represent a direct measurement of chemical migration from groundwater to the ground surface, only the 2009 soil gas data were used in this HHRA. (The results of the 2008 HHRA using groundwater data and modeling and the 2009 update are compared and discussed in Section 7.0.)

Given the reduction in uncertainty associated with the use of soil gas versus groundwater data in predicting concentrations in indoor air due to vapor intrusion, very conservative (protective) assumptions were applied in this HHRA. For instance, the *maximum detected concentration* of each chemical of potential concern (COPC), including total petroleum hydrocarbons – gasoline range (TPH-Gas) was assumed to be uniform across the Site, regardless of where the maximum detected concentrations were reported. In addition, it was assumed that all maximum detected concentrations were from samples collected at 5 feet bgs, though some were collected at 8 feet bgs. Other conservative assumptions were employed in the HHRA, which are described later in this report. In this manner, the results of the HHRA provide a conservative risk estimate for all receptors of concern based on more accurate chemical transport estimates than in previous iterations of HHRAs for this Site.

To provide current present-day concentration data in soil gas, data from four soil gas wells in 2009 were evaluated. Samples from two separate depths (5 feet bgs and 8 feet bgs) were collected from two of the locations (OMW-36 and HJMW-22). All data were reviewed for quality and usability and found to be suitable for risk assessment, with the exception of HJMW-22 at 8 feet bgs (and its duplicate), as this sample location was not collected from within a tight sample train. (As can be seen by review of Table 1, exclusion of this 8-foot depth sample does not affect the risk assessment, as maxima were detected primarily at the HJMW-22 5-foot depth or, for TPH, at the OMW-43 8-foot depth). As previously stated, the maximum detected concentration was selected as the environmental point concentration (EPC), regardless of its depth.

2-Propanol (also known as isopropyl alcohol or rubbing alcohol) was detected in all 7 samples considered for use in the HHRA update. 2-Propanol is a common laboratory contaminant and was used as a leak detection compound associated with the soil vapor sampling effort. Thus, this analyte is not considered a COPC in this HHRA

1.2 Data Adequacy and Representativeness

Groundwater data reviewed for the 2008 HHRA update were indicative of a stable or declining plume of petroleum constituents, including benzene, toluene, ethylbenzene and total xylenes (BTEX) and methyl tert-butyl ether (MTBE) as concentrations were generally much higher in the early portion of the timeline than in more recent years). The soil gas data collected in 2009 support this assumption, as none of the detected concentrations of any COPCs, including TPH-Gas, are more than one milligram per cubic meter (mg/m^3). The 2009 data do not suggest that an active source of contamination is present at the site.

1.3 Data Summary Statistics

The range and frequency of detection for each COPC, along with the maximum reported detection, are in Table A-2.1. As previously stated, the maximum detected concentration of each COPC is assumed to be uniform across the site at 5 feet bgs.

Two COPCs included in the 2008 and 2000 HHRAs, ethylbenzene and MTBE, were not detected in any of the soil gas samples collected in 2009 and were not included in this HHRA. In addition, tert-butyl alcohol (TBA), a breakdown product of MTBE, is found in shallow and deep groundwater, but was not detected in soil gas (see Table 2). However, TPH-Gas, which was not a COPC in the 2000 or 2009 HHRAs, was detected in nearly all of the soil gas samples and is a COPC in this update.

1.4 Physical Data for Site-Specific (Location-Specific) Modeling Comparison

To ensure conservatism, default vapor exposure models assume a uniform subsurface composed entirely of sand, the most permeable default classification in the EPA vapor intrusion model described further in Section 2.2. Reported risk results based on the conservative sand default are presented in Appendix A. However, measured physical parameters were reported for the soil gas locations surveyed in 2009 (see Appendix B). Assessment of these data enables comparisons between results using model defaults (see Appendix C) and results that incorporate the 2009 field data (see Appendix D).

Four model inputs for soil were measured in the field (see Appendix B) and entered in the model in place of the default values for sand (see Table D-1): effective permeability to air; dry bulk density; total porosity; and water-filled porosity. Effective permeability to air was measured in units of millidarcies (mD); the model requires this parameter to be entered in units of square centimeters (cm^2). The mD values for the two applicable locations from which maximum chemical concentrations were detected in soil gas samples (HJMW-22 for benzene, toluene, and xylenes and OMW-43 for TPH-GRO [modeled as hexane]) were converted to cm^2 by multiplying the mD values by 9.86923E-12. The effective permeability to air calculated using the default values for sand was obtained from the Intermediate Calculations worksheet of the Johnson & Ettinger Excel model.

The model input and output values are presented for the default and measured conditions in Table D-1. As presented in Table D-1, the use of measured soil parameters resulted in modeled indoor air concentrations (C_{bldg}) approximately two orders of magnitude less than the default sand conditions for location HJMW-22 and more than three times less than modeled indoor air concentrations for location OMW-43. As such, the use of default input values for sand in the HHRA represents an abundantly conservative approach at this Site.

2.0 EXPOSURE ASSESSMENT

A conceptual site model depicting potential exposure pathways and human receptors was developed based on local land and water uses associated with the Site as summarized below. Ultimately, this information was standardized into exposure pathways for assessment in the HHRA using EPA RAGS Part D standard Table 1 format (see Table A-1 of Appendix A in HHRA).

2.1 Receptors and Pathways

As a brief summary, receptors evaluated quantitatively in this HHRA include current commercial workers and residents that work or live on the land surface above the commingled groundwater plume. The average depth to groundwater in the five monitoring wells selected for analysis in the 2008 HHRA was less than 20 feet below grade for the period July 2000 through March 2008. (Soil gas samples were collected at depths of 5 and 8 feet bgs for the 2009 update; updated depth to groundwater data were not reviewed specifically for this update, but are not expected to vary significantly from previous historical elevations.)

Current and future commercial workers and residents were evaluated because of the potential for exposure to contaminants that may result in vapor intrusion indoors. A future on-site construction worker scenario is not being considered because soil is not impacted at the site and it is unlikely that exposure would occur to contaminants in groundwater at the Site, even if workers are asked to trench (e.g., for utilities).

Receptors selected for quantitative assessment at the Site thus include current and future adult and child residents and current and future adult commercial workers (potentially exposed to groundwater contaminants in indoor air). While a future construction worker could potentially contact contaminants in surface and subsurface soils, soil pathways are not assessed as part of this HHRA.

2.2 Exposure Point Concentrations and Intake Calculations

To determine hypothetical exposure points to assess, the current and future population activity patterns and the current location of contaminated media were analyzed. For the 2008 HHRA, five monitoring well locations were identified that generally agree with the locations of structures occupied by current and future commercial and residential receptors. The soil gas samples collected for the 2009 HHRA update correspond with the well locations selected for the 2008 HHRA. Because soil gas data generally provide more accurate depictions of subsurface conditions with regard to vapor migration in the vadose zone, a "worst-case" exposure point concentration (EPC) was assumed for each COPC; the maximum detected concentration of each COPC was assumed to be uniform in the subsurface across the entire site at a depth of 5 feet bgs, the shallowest depth from which soil gas samples were collected.

Table A-3.1 of Appendix A to the HHRA presents the soil gas EPCs used for this HHRA. The assumption of the maximum detected concentration as the EPC reduces potential uncertainty associated with a relatively small sample size (5 total valid soil gas analyses of each COPC including data from 4 separate locations and two shallow depths relative to the groundwater table, as shown in Table 1). This approach is further applicable since groundwater data reviewed for and included in the 2008 HHRA showed declining COPC concentrations over time in nearly every case for the five wells selected for that HHRA. Each of those five wells had been sampled at least 20 times since July 2000.

Exposure modeling was conducted using the maximum detected concentration of each COPC (EPC) to determine each receptor's indoor air EPC and subsequent intake or dose for each COPC. The soil gas version of the U.S. Environmental Protection Agency (2004) Johnson and Ettinger (1991) vapor intrusion model (SG-Screen, Version 3.1) was used to estimate concentrations of volatile COPCs in indoor air resulting from migration in soil gas. The EPA version of the vapor intrusion model is a one-dimensional, screening-level spreadsheet model that estimates convective and diffusive transport of chemical vapors emanating from soil gas into indoor spaces located directly above or near the source of contamination. The model provides an estimated attenuation coefficient that relates the vapor concentration in an indoor space to the vapor concentration at the source of contamination to estimate indoor air concentrations. A detailed description of the vapor intrusion model is provided in the *User's Guide for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings* (EPA 2003b).

Separate versions of the EPA spreadsheet model are available to address the following sources of vapor intrusion: Groundwater contamination, soil contamination, soil gas, and nonaqueous-phase liquids. For each of these versions, a screening-level version and an advanced version are also available. The screening version of each of the models limits user inputs to the most sensitive model parameters and incorporates only one soil stratum above the source. The advanced version of each of the models allows users to enter additional site-specific data for soil and building parameters and incorporates up to three soil strata for which soil properties may be varied.

The modeled indoor air concentrations are shown as the infinite indoor source building concentration term, $C_{building}$, on the Intermediate Calculations worksheet of the model output. For the Avis / National/ Payless Site, these sheets are presented in Tables C-2 through C-5.

Table C-1 summarizes model input parameters for soil and building physical properties and the assumptions used for each of the parameters. Default model assumptions were used unless site-specific data were available. Appendix B provides site-specific soil characteristics: because the parameter values showed some variation, the most conservative default assumption (i.e., sand) and the attendant sand porosities and organic carbon fractions were retained. This would allow the health risk assessment to be based on a "worst case" most permeable sandy area of the heterogeneous vadose zone overlying the former groundwater plume. Site-specific assumptions were used for the following parameters: soil gas contaminant concentrations, and depth below grade to soil gas. Building dimensions and soil type were based on default conservative values. Assumptions used for these parameters are discussed below.

Soil Gas Contaminant Concentrations. As previously noted, the maximum detected concentrations were used as contaminant concentration inputs to the model.

TPH-Gas Surrogate. In addition to the BTEX and MTBE components measured separately in soil vapor, TPH-Gas was selected as a COPC for this HHRA update; however, this complex mixture of aromatic and aliphatic compounds, as such, is not included in the SG-SCREEN model. To avoid leaving a data gap for TPH vapors in the gasoline range, a surrogate compound, hexane, was selected to represent migration of the TPH-Gas into indoor air. Hexane is a major component of the aliphatic fraction of gasoline and is considered an appropriately conservative surrogate for TPH-Gas.

Depth Below Grade to Soil Gas. The shallowest depth from which soil gas samples were collected (5 feet or 152 cm) was used in the model.

Soil Type. Based on geologic information provided for the four soil gas sampling locations (Appendix B), the soils sampled for soil gas are mostly silty sands with some local variation; however, for this conservative screening level HHRA, all soils were initially assumed to be sand (see Appendix C), which is the most permeable soil type in the model and will provide "worst-case" results. Only one soil stratum was assumed. In reality, a caliche (hard clay) layer is present in the subsurface in many locations at the site, which should act as a protective vapor barrier where present. For comparison, site-specific physical parameters were applied to the soil gas model (see Appendix D).

Residential and Commercial Building Dimensions. Due to the variation in building sizes and configuration in residential and commercial structures overlying the plume, the default model values for buildings and their foundation characteristics (e.g., fraction of foundation that is cracked, building indoor air volumes and air exchanges, etc.) were assumed across the site. Residential and commercial structures were assumed to be the same for purposes of simplicity and conservatism.

Table D-1 summarizes the modeled indoor air concentrations for each COPC. These indoor air concentrations are the EPCs shown in Table 3.3 of Appendix A, which were used to calculate daily doses and resultant hazards and risk from inhalation of chemicals that migrate upward to indoor air in residential and commercial structures above the plume.

A chemical intake is expressed as milligrams of chemical per kilogram of body weight per day (mg/kg-day) and was calculated for a reasonable maximum exposure (RME) scenario using the exposure parameters detailed in Table A-4 of Appendix A. The RME scenario represents the highest exposure reasonably expected to occur at a site and is calculated using the EPCs and RME parameters. An alternate, central tendency (CT) scenario may also be calculated as the average exposure expected to occur at the site. Details of the algorithms used to calculate chemical intake are provided in EPA guidance as reproduced on Table A-4.

3.0 TOXICITY ASSESSMENT

The most recent data in the IRIS, an EPA toxicity database, were used where available. If a toxicity value was not available through IRIS, EPA's Provisional Peer-Reviewed Toxicity Values (PPRTV) were considered. If neither of the first two sources had a value, third-tier sources specified in the EPA toxicity data selection hierarchy (EPA 2003a). Toxicity values available in IRIS for benzene, toluene, and xylene; these were utilized in the HHRA update.

Toxicity criteria and/or data for TPH are not presented in IRIS; some controversy exists over the appropriateness of risk evaluations for TPH in general due to the uncertain chemical nature of the mixture in the environment, especially for weathered petroleum products. As such, few universally accepted toxicity criteria exist for TPH. A group of experts from academia, government and industry came together in 1997 as the Total Petroleum Hydrocarbons Criteria Working Group (TPHCWG) which resulted in a set of recommended toxicity criteria (Reference Doses [RfD] and Reference Concentrations [RfC]) that could be used in forward risk assessments such as this one. As such, in order to calculate health risks that are transparent and straight-forward, the TPHCWG toxicity RfCs were used in this evaluation, with some modification to account for the dataset's lack of distinction between aromatic and aliphatic fractions of TPH (described in Section 3.4). Toxicity values used in the HHRA are presented in Tables A-5 and A-6 of Appendix A. Brief toxicity profiles for the COPCs detected in groundwater at the Site are included in the following sections (see the RAGS Part D standard Tables 5 and 6 in Appendix A for more information).

3.1 Benzene

Benzene is a highly volatile organic compound; as such, the primary route of exposure is inhalation. It is readily absorbed from the GI tract following oral ingestion because of its lipophilic nature. In contrast, dermal absorption of benzene is limited (EPA 2005a). Benzene is distributed to fatty tissues in the body and has an affinity for adipose and nervous tissue, bone marrow, liver, spleen, and blood. Benzene is metabolized in the liver primarily to phenol which is subsequently excreted in the urine. Long-term exposure to benzene can result in central nervous system (CNS) and gastrointestinal effects; however, the primary pathological target is the bone marrow. Symptoms include anemia and thrombocytopenia as well as other hematologic abnormalities. Triggered by chronic benzene exposure, these hematologic abnormalities may progress to leukemia. Both the chronic oral RfD (0.004 mg/kg-day) and chronic inhalation RfC (0.03 mg/m^3) are based on a decreased lymphocyte count in an occupational study and include uncertainty factors of 300 (EPA 2005a). Benzene is classified as a class A weight-of-evidence carcinogen based on nonlymphocytic leukemia associated with occupational exposures and neoplasia in experimental animals (EPA 2005a). An oral SF of 0.055 per mg/kg-day and an inhalation UR factor of 0.0000078 per $\mu g/m^3$ have been established by EPA (2005a).

3.2 Toluene

The primary effect associated with inhalation exposure to toluene is central nervous system depression. Per IRIS, toluene is a class D carcinogen (EPA 2005a) and hence, only noncarcinogenic effects are quantified. The inhalation RfC of 5 mg/m^3 is based on CNS effects and incorporates an uncertainty factor of 10.

3.3 Xylenes (total)

The primary effect associated with inhalation exposure to xylenes is central nervous system depression. Per IRIS, xylene is a class D carcinogen (EPA 2009) and hence, only noncarcinogenic effects are quantified. The inhalation RfC of 0.11 mg/m^3 is based on CNS effects and incorporates an uncertainty factor of 300.

3.4 TBA (Tert-butyl alcohol)

As a breakdown product of MTBE in Site groundwater sampled through 2008, TBA is a potential COPC. However, TBA was not a detected analyte in soil gas in the Site vadose zone, and therefore the inhalation pathway for exposure to TBA in groundwater is incomplete. Further, the IRIS toxicity assessment of TBA is not expected to be complete until September 2012 (EPA 2009) and therefore, a data gap is presented in the toxicity assessment for TBA. Other states are developing interim toxicity reference values for TBA, but without data to represent a TBA concentration in soil gas, the inhalation pathway at this Site is incomplete. Therefore, the toxicity assessment data gap for TBA is not significant.

3.5 TPH-Gasoline Range

The TPHCWG hazard assessment methodology divides the measured TPH into fraction-specific mixtures (i.e., aromatic and aliphatic), as well as by the length of carbon chains (e.g., C_6 = 6 connected carbon atoms), which also differentiates generally between gasoline, diesel, and motor oil ranges. These fractions and ranges are represented by surrogate compounds, as little valid toxicity data is possible from the mixtures themselves. The surrogates are chosen based on toxicity, mobility, and analytical considerations. The surrogates upon which the various RfDs/RfCs are based in the TPHCWG guidance are described below, by fraction and carbon range.

Aromatic Fraction: $C_7 - C_8$ range (gasoline)

In this HHRA update, the RfC for this group of compounds is assumed to represent the aromatic fraction (assumed to equal half of the total detected concentration in each sample, the other half being aliphatic) of the gasoline-range TPH. Only three of the seven identified compounds in the carbon range have inhalation RfC values for evaluation of risks from inhalation of TPH: toluene (0.4 mg/m^3), ethylbenzene (1.0 mg/m^3), and styrene (1.0 mg/m^3) were used to reach a representative inhalation RfC for the carbon range. To remain conservative, the value 0.4 was recommended, and is believed to safely represent the carbon range. However, for this Site, BTEX were measured in soil vapor (and assessed for health hazards) separately as key indicator compounds, so this assessment of the TPH-Gas as if it were comprised of these toxic components is abundantly conservative.

Aliphatic Fraction: including $C_5 - C_8$ (gasoline)

For this HHRA update, the RfC for this range is assumed to represent half of the gasoline range TPH EPC. More RfC data were available for aliphatic compounds than the aromatics, reducing uncertainty in the reference values. n-Hexane, by far the most toxic compound in this range, has been extensively studied and has an RfC of 0.2 mg/m^3. The recommended RfC for the range was calculated at 18.4 mg/m^3, from which the RfD was extrapolated to 5.0 mg/kg-day. The RfD for commercial hexane demonstrates that the toxicity of n-hexane is unique in the carbon fraction, since both the RfD for commercial hexane and n-heptane are two orders of magnitude greater than the RfD for n-hexane. The study also reveals that n-hexane is less toxic when mixed with other hydrocarbons. The commercial hexane mixture is considered the most appropriate surrogate because it most accurately represents the fraction.

Modification of TPHCWG Toxicity Criteria

Because analytical data for TPH from the site do not differentiate between aromatic and aliphatic fractions, it was assumed that each detected value was comprised of half aromatic compounds and half aliphatic compounds. As such, RfC was assumed to be the average of the RfC for the aromatic and aliphatic fractions. The resulting RfC used in this HHRA is therefore: $\mathbf{(0.4\ mg/m^3 + 18.4\ mg/m^3)/2 = 9.4\ mg/m^3}$

4.0 RISK CHARACTERIZATION

Both cancer and noncancer risks were calculated for the Avis / National / Payless commingled plume site. The risk characterization combines the exposure assessment (and intake calculations) and toxicity evaluation, resulting in the final cancer risks and noncancer HI values for each receptor and pathway. For cancer risk, the intake determined is multiplied by cancer potency values determined in the toxicity assessment. Results are expressed in scientific notation as an incremental probability of contracting COPC-related cancer. In assessing cancer risk probabilities posed by potential exposure to chemicals at a site, the National Contingency Plan (NCP) establishes an excess cumulative cancer risk of 1E-06 as a "point of departure" for establishing remediation goals (EPA 1994). Cumulative cancer risks in the range of 1E-06 to 1E-04 fall within the "risk management range" and are generally considered acceptable, depending on site-specific factors such as the potential for exposure, technical limitations of remediation, and data uncertainties.

Noncancer health hazards are evaluated by calculating hazard quotients (HQ) and hazard indices (HI). This is accomplished by comparing the estimated daily intakes of COPCs, which are averaged over the period of exposure, to chemical- and route-specific toxicity reference doses identified in the toxicity assessment. This hazard ratio is compared to 1, with HI greater than 1 indicating potential for a noncancer health effect.

5.0 QUANTITATIVE AND QUALITATIVE RESULTS SUMMARY

Each of the risk evaluations for the Avis / National / Payless commingled plume site receptors is summarized below. Quantitative details are presented in Tables A-7.1 through A-7.2 for the RME case in Appendix A, with an overview in Table 2.

5.1 Current and Future Resident Noncancer Health Hazards and Cancer Risks

Based on current conditions at the Site, the most reasonable exposure pathway for future residents is inhalation of vapors indoor due to potential migration of vapors via soil gas from the shallow groundwater underlying current and future (if redevelopment occurs) buildings. Residential exposures to the impacted groundwater zone via direct ingestion and dermal contact were not evaluated because no current residents receive water from the shallow water table and residents in the future would also be expected to receive their tap water from the Las Vegas municipal water supply. Exposures to surface soil were not evaluated as there were no COPCs detected in shallow soil (given their volatile nature), and the property is mostly paved, covered by structures, or landscaped. Because cancer-producing exposures (i.e., exposures to benzene) are considered cumulative for a life-long resident near the Site, a cumulative lifetime cancer risk of 1E-07 was calculated for adult and child residents (see Table 2) using soil gas data from 2009 and RME assumptions, including the "worst case" sand model (Appendix C). This RME case, using maximum EPC concentrations, assumption of sandy soil, and shallowest sample collection depth, did not result in a potential cancer risk greater than the acceptable 1E-06 risk management range for residential risks due to vapor intrusion. No noncancer hazard index exceeded 1. Due to their greater intake relative to their body weight, a child's health hazard is greater than an adult's and thus is represented on the summary (Table 2).

When site-specific (boring-specific) physical parameters are applied to the vapor model (see Appendix D), concentrations (and thus, risks) are one hundred times lower (see Table D-1).

5.2 Current and Future Commercial Worker Noncancer Health Hazards and Cancer Risks

The assumptions described above for characterization of risks to current and future residents were also employed for current and future commercial workers employed in the businesses overlying the plume (e.g., hotel employees, auto rental attendants). Due to the volatility of the COPCs at this Site and the rapid dispersion in ambient air, exposures to COPCs by commercial workers outside buildings are expected to be lower than those in workers inside. Therefore, risks to indoor workers (where volatile COPCs accumulate) were modeled to be more conservative than (lower) risks that would be modeled for outdoor workers. The cancer risk calculated for current and future commercial workers due to benzene exposure using the maximum detected concentration as the EPC was 2E-08 (see Table 2). The noncancer hazard index was less than 1. When site-specific (boring-specific) physical parameters are applied to the vapor model (see Appendix D), concentrations (and thus, risks) are one hundred times lower (see Table D-1).

5.3 Qualitative Construction/Utility Worker Health Risks

Exposures to vapors during construction were not quantitatively evaluated because future construction activities are not likely to hypothetically occur at depths that could contact the uppermost groundwater-bearing unit, which occurs at approximately 13-20 ft bgs (see the 2008 HHRA) at the Site. As soon as a trench might contact the water table, the volatile nature of the organics would dictate that they would evaporate to ambient atmosphere. Groundwater ingestion and dermal contact are not expected to be complete at the Site. If a trench were to intercept the water table, it would have to be dewatered in order for construction to proceed and thus only momentary direct exposure is hypothetically possible.

6.0 UNCERTAINTY ANALYSIS

Virtually every step in the HHRA process requires numerous assumptions, all of which contribute to uncertainty in the risk evaluation. For the Avis / National / Payless commingled plume site, the following contributed most significantly to uncertainty:

1. **Environmental Point Concentrations.** The selection of an EPC for entry in a model is a major source of uncertainty due to potential variation in the concentrations of COPCs across a site. In order to remove uncertainty and provide more protective estimates of risk, the maximum detected concentration of each COPC in soil gas samples collected in 2009 was assumed to be the EPC across the site. The use of the maximum concentrations is considered conservative and represents a "worst case" condition.

2. **Use of Soil Gas Data Instead of Groundwater Data**. Previous iterations of the HHRA for this site were based on modeling of COPCs in groundwater into the indoor air of structures overlying the plume. A key component of this migratory pathway is the fact that COPCs move through the vadose zone in soil gas. As such, the concentrations of COPCs in soil gas represent the actual movement of chemicals through the subsurface as opposed to modeled estimates of transport into and through soil gas from groundwater, which requires often oversimplifying assumptions regarding soil type and characteristics (e.g., porosity, air space, carbon content, etc.), groundwater characteristics, and variations in the subsurface environment between the water table and surface. Essentially, the use of soil gas data instead of groundwater data removes the layers of uncertainty associated with the transport of chemicals to soil gas from groundwater.

   Further, soil gas data provides an accurate account of which compounds are actually volatilizing from groundwater at the site. For example, MTBE (and its breakdown product TBA) was historically detected in groundwater samples and was employed as a COPC in the 2008 HHRA; however, MTBE was not detected in any soil gas samples collected from wells co-located with wells evaluated in the 2008 HHRA.

TBA was also not reported in soil gas. This fact may reflect the fact that MTBE and TBA have attenuated to negligible levels in groundwater since the 2008 HHRA, but more likely reflects the fact that MTBE and TBA are highly water soluble and there may be factors at the site (e.g., caliche or clay layers present or factors of groundwater chemistry at the site) that are preventing the MTBE and TBA from migrating in soil gas as opposed to preferentially remaining in groundwater. The reporting limits for MTBE in the soil gas data were sufficiently low that there is little chance that MTBE is present in soil gas at levels that could lead to health concerns. The soil gas data used in this HHRA update is recent (2009) and reflects current conditions.

3. **Concentrations are Stable or Declining.** Assuming the trend identified in the 2008 HHRA holds, the concentrations of petroleum constituents at the Avis / National / Payless commingled plume site are expected to continue to decline. With concentration reductions, a corresponding reduction in the baseline risks will also result.

4. **Exposure Points for Future Use is Problematic.** To err on the side of conservatism, the subsurface at the site was assumed to be uniform and to contain COPCs at the maximum detected concentrations at a depth of five feet bgs. This assumption reduces uncertainty associated with variability in the actual locations of future structures.

5. **Models Contain Uncertain Assumptions.** As detailed in the User's Guide (EPA 2003b) that accompanies the model, the Johnson & Ettinger vapor model (EPA 2004) contains inherent uncertainties. To address this uncertainty, a significant amount of conservatism has been incorporated into the vapor intrusion modeling process. These assumptions are likely to result in estimates of indoor air concentrations that are higher than actual concentrations. Some of the conservative assumptions of the model are listed below:

- Loss Mechanisms. Absence of loss mechanisms, such as biodegradation and vapor-phase adsorption, result in overestimation of vapor emissions from in indoor air.
- Depleting Contaminant Source. Use of a nondepleting, constant source results in an unlimited supply of contaminated vapor and an overestimation of vapor emissions to indoor air.
- Water Movement. Absence of water (and dissolved chemical) movement through unsaturated soil results in an overestimation of chemical mass in vapor-phase available for transport to indoor air.
- Neutral or Positive Pressurization. Assumption of continuously under-pressurized buildings neglects significant periods where neutral or positive pressurized conditions exist results in an overestimate advective transport of contaminated vapors to indoor air.
- One-dimensional Transport. The assumption of vapor transport under a single (vertical) dimension ignores the potential for vapor migration in multiple directions away from the source area, resulting in an overestimation of vapor emissions and higher indoor air concentrations.

In addition, the caliche layers present at the Site were not taken into account and the natural vapor barrier they provide was thus not factored in as a protective mechanism against indoor vapor intrusion. Therefore, the residential and commercial worker inhalation risks predicted based on predicted vapor concentrations in indoor air also contain uncertainty. All of these assumptions conservatively produce a "worst case" scenario to overpredict indoor air concentrations and hence, a resulting overprediction of health impacts. When site-specific (boring-specific) physical parameters are applied to the vapor model (see Appendix D), concentrations (and thus, risks) are one hundred times lower (see Table D-1).

6. **"Reasonable Maximum" versus "Central Tendency" Exposures Overestimate Averages.** Given that the RME case is an "upper bound" estimate of each exposure parameter, more "average" exposures along a central tendency would be expected to correspond to significantly lower health risks and hazards. A reduction of at least 40 percent of the cancer risk is common when CT parameters (rather than RME parameters) are employed for the risk calculations. .

7. **Cancer Estimates are Upper-Bound Probabilities: Toxicity Values are Uncertain.** Cancer potency values are used to estimate an upper-bound lifetime probability of an individual developing cancer as a result of exposure to a particular level of a carcinogen, and conservatively and represent the upper-bound limit of the carcinogenic potency of each chemical. The actual risk posed by each chemical in humans is unknown, but is likely to be lower than the calculated risk and may even be as low as zero (EPA 1989). Similarly, noncancer reference doses used in the risk assessment had uncertainty and modifying factors of 90 to 300.

8. **Science Continues to Reduce Uncertainty in Toxicity Assessment.** Since aromatic indicator compounds BTEX were reported separately apart from the TPH-Gas range analytical result, no data gap is left in the toxicity assessment for the aromatic fraction; however, the aliphatic fraction of TPH in the gasoline range is accompanied by some uncertainty. A third-tier source (TPHCWG toxicity value) that serves as the basis for the TPH-Gas health risks is advised as the level of consensus and peer review is different from that in the first two tiers advised in EPA (2003) guidance. Therefore, the state of the science is represented in the site-specific HHRA but includes the potential for revision in the future responsive to new studies that eliminate more of the toxicological uncertainty.

9. **Future Toxicity Assessments Cannot be Predicted.** If TBA were found in soil gas such that the inhalation pathway could be complete, then a toxicity criterion to represent TBA in this HHRA could be assigned from third-tier (state) sources, pending the EPA IRIS assessment of TBA, which is not expected before 2012. However, since TBA behaves similarly to MTBE in groundwater and the vadose zone, the absence of MTBE in soil gas indicates that, more likely than not, TBA is also absent from the vadose zone. Use of a third-tier source in toxicity assessment would result in further uncertainty, but given the lack of TBA concentration data in the soil gas, this HHRA does not quantify this uncertain health risk.

7.0 CONCLUSIONS AND COMPARISON WITH PREVIOUS RESULTS

In conclusion, the results of this HHRA update indicate that current and hypothetical future exposures to COPCs in soil gas (from groundwater) at the Avis / National / Payless commingled plume site based on existing data were estimated to result in cancer risk probabilities and noncancer hazards lower than EPA's acceptable cancer risk of 1E-06 and below the noncancer threshold of 1, respectively. Exposures to vapors indoors by current and future residents and commercial workers due to migration of VOCs in groundwater through the subsurface into buildings are predicted to decline, given the reductions in chemical concentrations in monitoring wells over the past three years.

Risk estimates in the 2008 HHRA for this Site, which used groundwater data, were about two orders of magnitude higher (1E-05 for adult and child residents in the 2008 HHRA) than the risk estimates calculated in the 2009 HHRA update. Based on the factors described above, this illustrates that modeling of chemicals in groundwater can lead to overestimation of risks due to extra conservative assumptions related to transport from groundwater to soil gas, an intermediate step removed from the calculations when soil gas data are used.

Other points of departure from the 2008 HHRA are the fact that MTBE and ethylbenzene were not included as COPCs since they were not detected in any of the soil gas samples collected in 2009. MTBE contributed to cancer risks and noncancer hazards in the 2008 HHRA, while ethylbenzene was a minor contributor to noncancer health effects. Conversely, TPH-Gas was evaluated as a COPC in the 2009 update but was not considered a COPC in the 2008 HHRA. The maximum detected concentration of TPH-Gas (900 $\mu g/m^3$) used as the EPC is high compared with the other COPCs and migration of this compound was modeled using hexane as a surrogate. It is considered unlikely that MTBE and/or ethylbenzene would have resulted in a noncancer health effect greater than that calculated for TPH-Gas.

The concentrations of most COPCs in groundwater in most wells were observed to have significantly declined over the last 3 years; the subsequent reduction in risk associated with lower chemical concentrations is probably reflected in the results of this HHRA update based on soil gas data. The models utilized in the 2008 and 2009 HHRAs were both developed by EPA based on Johnson and Ettinger (1992) principles and are very similar, except that the 2009 HHRA update did not include conservative assumptions and calculations associated with the initial transport of COPCs from groundwater into soil gas. All exposure parameters and factors associated with modeled structures overlying the plume were the same.

Future risks are likely to decline even further. These findings lend further weight of evidence to the conclusion that cumulative cancer risks and noncancer health effects at the Avis / National / Payless commingled plume are less than significant.

8.0 REFERENCES

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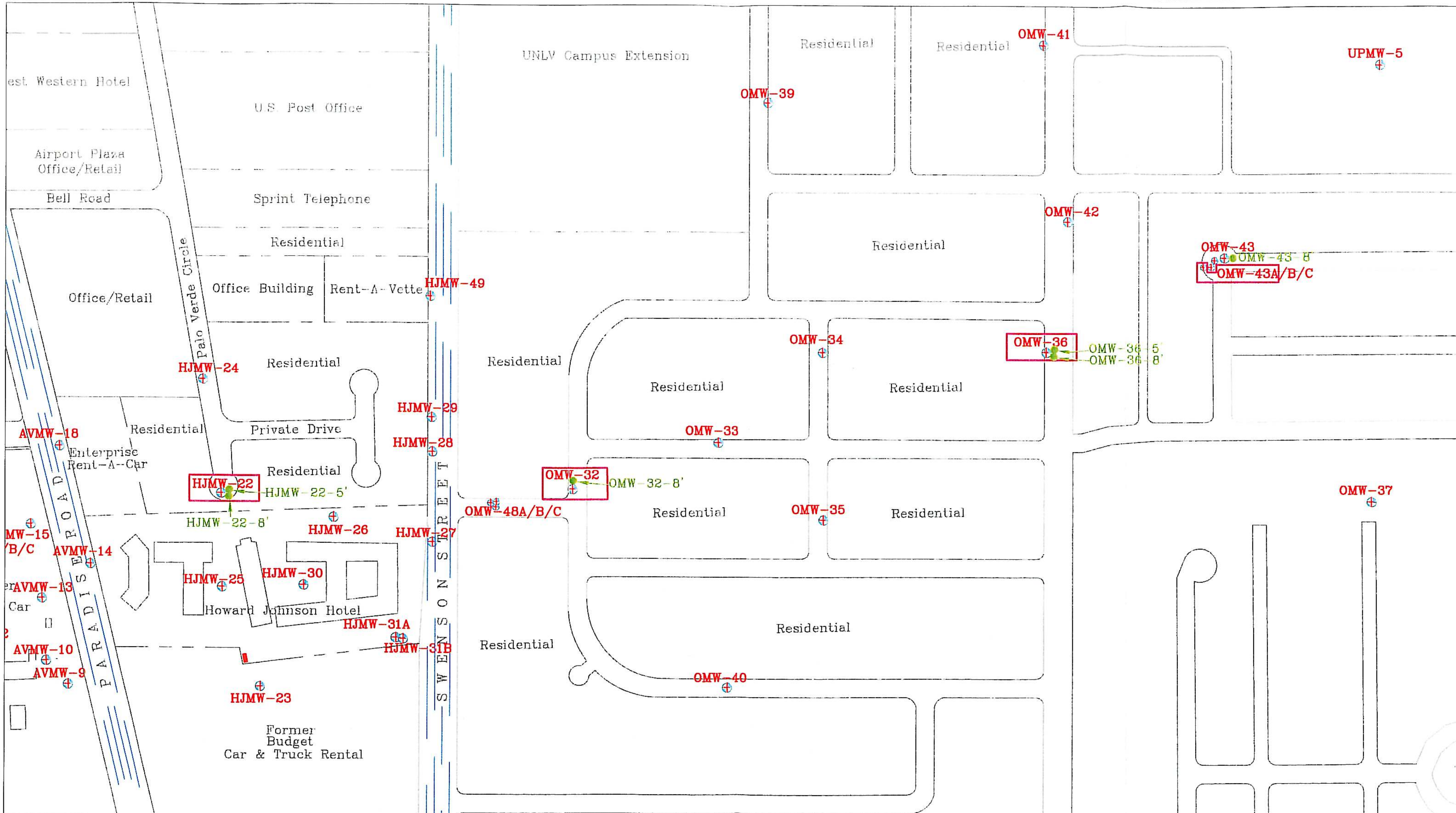
FIGURE



LEGEND

HJMW-22-8'	Soil Gas Survey Monitoring Wells	OMW-33	Monitor Wells Utilized for Risk Assessment
AVMW-10	Monitor Well on Avis Site	HJMW-24	Monitor Well on Howard Johnson Site
OMW-33	Off-site Monitor Well	AVMW-45A/B/C	Clustered Monitor Wells

N

0 100 200 400

Approximate Scale: 1 inch = 200 feet

BROADBENT & ASSOCIATES, INC.
ENGINEERING, WATER RESOURCES & ENVIRONMENTAL

Prepared By: VLR Approved By: JEH Date: 7/31/09

Soil Gas Survey Boring Locations
Former Avis Rent A Car Services, Inc. Facility
Las Vegas, Nevada
Project No. 95-01-150

Drawing
1

TABLES

Table 1
Soil Gas Data Summary
Avis / National / Payless Commingled Groundwater Plume Area
Las Vegas, Nevada

July 2009 Soil Gas Data

Well	Depth	Benzene	Toluene	Ethylbenzene	Total Xylene	MTBE	TPH-Gas
	Feet Below Grade	ug/m³	ug/m³	ug/m³	ug/m³	ug/m³	ug/m³
OMW-43	8'	10	29	<5.6	<5.6	<4.6	**900**
OMW-36	5'	<4.2	15	<5.7	<5.7	<4.8	270
OMW-36	8'	9.2	29	<5.8	<5.8	<4.8	310
OMW-32	8'	6.5	28	<6.0	<6.0	<5.0	390
HJMW-22	5'	**13**	**52**	<5.8	**11**	<4.8	860
HJMW-22	8'	12	36	<16	<16	<13	<300
HJMW-22_DUP	8'	9	37	<5.7	8.6	<4.8	780

Note: Laboratory data validation indicated that the 8-foot HJMW-22 sample (and its duplicate) was not collected from a tight sample train (i.e., the tracer isopropyl alcohol concentrations were high). Thus, the HHRA did not use this sample depth. Maxima are shown in shaded bold text.

TABLE 2
RISK ASSESSMENT SUMMARY:
CURRENT AND FUTURE INHALATION RISKS AND HAZARDS, 2009 SOIL GAS DATA
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

RESIDENTS

	Maximum Detected Concentration
Child Cancer Risk	5.3E-08
Adult Cancer Risk	9.0E-08
Total Cancer Risk	1.4E-07
Child Hazard Index	0.004

COMMERCIAL WORKERS

	Maximum Detected Concentration
Adult Commercial Worker Cancer Risk	2.3E-08
Adult Hazard Index	0.0004

The EPA (acceptable) risk management range is from 1E-06 (1 in 1 million) to 1E-04 (1 in 10,000). An incremental lifetime cancer risk within (or below) this range is considered acceptable and therefore

A hazard index of less than 1 indicates that exposures do not exceed the EPA acceptable reference dose for the analytes considered.

Given that the toxicity reference values and exposure input parameters are only known to one significant digit, the results are also only significant to one digit. Additional digits and decimal places are shown in the calculations to enable mathematical accuracy checks, but the additional decimals are not significant. No calculated risks are above the EPA cancer risk threshold of 1 in 1,000,000. The hazard index was well below unity for a future child resident.

APPENDICES

APPENDIX A

Risk Assessment Tables

TABLE A-1
SELECTION OF EXPOSURE PATHWAYS
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

Scenario Number	Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
1A	Future	Groundwater	Groundwater	Top of Water Table During Trenching Work	Construction Worker	Adult	Dermal	None	If a trench was deeper than 8 ft bgs and dewatering was not employed, a worker could be affected during shallow utility or construction work. However, the uppermost groundwater-bearing unit at this site is located at depths greater than 8 feet and, therefore, a worker performing tasks in a trench would not be expected to have contact with affected groundwater. Hence, this pathway is incomplete and the scenario was not quantitatively evaluated.
1B						Adult	Inhalation	None	
1C				Hypothetical Future Toilet and Sink (non-drinking water)	Commercial Worker	Adult	Dermal	None	Municipal sources of water are available and the shallow water table is not a primary aquifer due to high total dissolved solids (TDS) content.
1D						Adult	Inhalation	None	
1E				Domestic Well (At the Tap)	Resident	Child	Dermal	None	No future on-site residential use of shallow groundwater is projected. No pathway is complete for off-site residential direct contact via ingestion, dermal, or inhalation during whole-house domestic use of groundwater, given that a municipal source of water is available.
1F						Child	Inhalation	None	
1G						Child	Ingestion	None	
1H						Adult	Dermal	None	
1I						Adult	Inhalation	None	
1J						Adult	Ingestion	None	
2A	Future	On-Site Soil	Soil (to 8 feet bgs)	Soil in Construction/Utility Repair Trench	Construction Worker	Adult	Dermal	None	A future Construction Worker could contact soil during shallow utility or construction work (to a maximum depth of 8 feet). However, no bulk soil data are available to quantify exposure to vapors. Vapors are unlikely to persist in bulk soils during disturbance as the constituents will volatilize.
2B						Adult	Ingestion	None	
2C						Adult	Inhalation	None	
2D			Surface Soil (to 2 feet bgs)	Surface Soil at Outdoor Workplace	Commercial Worker	Adult	Dermal	None	Future Industrial Worker exposures, or even Residential exposures, would not include exposure to volatile organic constituents (VOC) as the 0-2 ft horizon is open to atmospheric pressures and absent VOCs.
2E						Adult	Ingestion	None	
2F						Adult	Inhalation	None	
3A	Future	Soil Gas (from Groundwater)	Air	Air in First-Floor Living Spaces	Resident	Child	Inhalation	Quant	Current and future residences could be affected by subsurface vapor intrusion from soil gas via the vadose zone. A small, default home is assumed to be located atop each monitoring well location, where vapors migrate upward through the vadose zone, infiltrate the slab of the residence, and accumulate inside the future home.
3B						Adult	Inhalation	Quant	
3C	Current/Future	Soil Gas (from Groundwater)	Air	Air in Future On-Site Commercial Buildings	Commercial Worker	Adult	Inhalation	Quant	Current and future commercial workers could be affected by subsurface vapor intrusion from soil gas via the vadose zone. A small, default structure is assumed to be located atop the monitoring well location where the maximum soil gas concentrations were detected, where vapors migrate upward through the vadose zone, infiltrate the slab of the residence, and accumulate inside the future home.

Notes:
Quant = Quantitative assessment. Qual = Qualitative assessment.

TABLE A-2.1
OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
GROUNDWATER DIRECT CONTACT
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

Scenario Timeframe: Current and Future
Medium: Soil Gas
Exposure Medium: Indoor Air

Exposure Point	CAS Number	Chemical	Minimum Concentration (1)	Maximum Concentration (1)	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits [a] (ug/m^3)	Concentration Used for Screening (2)	Background Value	Screening Toxicity Value (N/C) (3)	Potential ARAR/TBC Value	Potential ARAR/TBC Source (ug/m^3)	COPC Flag	Rationale for Selection or Deletion (4)
Indoor Air		BENZENE	6.5	13	ug/m^3	HJMW-22	6 / 7	4.1 - 12.0	13	--				YES	Detection
		TOLUENE	15	52	ug/m^3	HJMW-22	7 / 7	4.9 - 14	52	--				YES	Detection
		ETHYLBENZENE	ND	ND	ug/m^3	NA	0 / 7	5.6 - 16	ND	--				NO	ND
		XYLENES	8.6	11	ug/m^3	HJMW-22	2 / 7	5.6 - 16	11	--				YES	Detection
		MTBE	ND	ND	ug/m^3	NA	0 / 7	4.6 - 13	ND	--				NO	ND
		TBA	ND	ND	ug/m^3	NA	0 / 7	16 - 45	ND	--				NO	ND
		TPH - gasoline	270.0	900	ug/m^3	OMW-43	6 / 7	100 300	900	--				YES	Detection

Notes:

(1) Minimum/maximum detected concentration in soil gas samples collected in July 2009.

(2) Maximum concentration used as screening value.

(3) Screening values are risk-based screening levels from the Region 9 Preliminary Remediation Goals (PRG) (EPA 2004) for the tap water scenario. However, the noncancer-based PRGs were divided by 10 (to correspond to a chemical-specific hazard quotient of 0.1); the carcinogen-based PRGs were not modified. Because Region 9 has not updated the PRGs since 2004, the Region 6 medium-specific screening levels (MSSL) were consulted for comparison. With the exception of toluene (where both values are shown), the 2004 PRGs and 2008 MSSLs are the same.

(4) Rationale Codes
Selection: Detected in Soil Gas
Deletion: Not Detected in Soil Gas
Shading indicates chemicals marked as COPCs.

Definitions: -- = Not available
ARAR/TBC = Applicable or relevant and appropriate requirement/to be considered
C = Carcinogenic
CAS = Chemical Abstract Service
COPC = Chemical of potential concern
MTBE = Methyl tert-butyl ether
N = Noncarcinogenic
ND = Not detected
TBA = Tert-butyl alcohol
TPH = Total petroleum hydrocarbons

ug/m^3 = Micrograms per cubic meter

Reference:

EPA 2004. "EPA Region 9 Preliminary Remediation Goals (PRG) 2004." Available online at http://www.epa.gov/region09/waste/sfund/prg/index.html#prgtable. December 28.

TABLE A-3
MAXIMUM EXPOSURE POINT CONCENTRATION SUMMARY
GROUNDWATER
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

Scenario Timeframe: Current and Future
Medium: Soil Gas
Exposure Medium: Indoor Air

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean (1)	95% UCL (Distribution) (1)	Maximum Concentration (Qualifier)	Exposure Point Concentration			
						Value	Units	Statistic (2)	Rationale
Tap Water from Underlying Shallow Groundwater	BENZENE	ug/m^3	10.0	NC	13	13	ug/m^3	Maximum Detected Concentration	Most Conservative
	TOLUENE	ug/m^3	32.3	NC	52	52	ug/m^3	Maximum Detected Concentration	Most Conservative
	ETHYLBENZENE	ug/m^3	NA	NC	NA	NA	ug/m^3	NA	Not Detected
	XYLENE	ug/m^3	9.8	NC	11	11	ug/m^3	Maximum Detected Concentration	Most Conservative
	MTBE	ug/m^3	NA	NC	NA	NA	ug/m^3	NA	Not Detected
	TBA	ug/m^3	NA	NC	NA	NA	ug/m^3	NA	Not Detected
	TPH-Gasoline	ug/m^3	585	NC	900 B	900	ug/m^3	Maximum Detected Concentration	Most Conservative

Notes:

B
MTBE Methyl tert-butyl ether
NA Not applicable
NC Not calculated
TBA Tert-butyl alcohol
TPH Total petroleum hydrocarbons
95% UCL 95 percent upper confidence limit
ug/m^3 Micrograms per cubic meter

TABLE A-4
VALUES USED FOR DAILY INTAKE CALCULATIONS
AIR EXPOSURES
REASONABLE MAXIMUM EXPOSURE
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

Scenario Timeframe:	Current and Future
Medium:	Soil Gas
Exposure Medium:	Indoor Air

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name (1)
Inhalation	Resident	Adult	Indoor Air	CA	Chemical Concentration in Air	EPC	mg/m^3	Modeled (see Appendix D)	Intake (mg/kg-day) =
				InhR	Inhalation Rate	0.83	$m^3/hour$	EPA 1997	(CA x InhR x ET x EF x ED) / (BW x AT)
				ET	Exposure Time	24	hours/day	EPA 1991	
				EF	Exposure Frequency	350	days/year	EPA 1991	
				ED	Exposure Duration	24	years	EPA 1991	
				BW	Body Weight	70	kg	EPA 1991	
				AT-C	Averaging Time - Cancer	25,550	days	EPA 1989	
				AT-NC	Averaging Time - Non-Cancer	8,760	days	EPA 1989	
		Child	Indoor Air	CA	Chemical Concentration in Air	EPC	mg/m^3	Modeled (see Appendix D)	Intake (mg/kg-day) =
				InhR	Inhalation Rate	0.42	$m^3/hour$	EPA 1997	(CA x InhR x ET x EF x ED) / (BW x AT)
				ET	Exposure Time	24	hours/day	EPA 1991	
				EF	Exposure Frequency	350	days/year	EPA 1991	
				ED	Exposure Duration	6	years	EPA 1991	
				BW	Body Weight	15	kg	EPA 1991	
				AT-C	Averaging Time - Cancer	25,550	days	EPA 1989	
				AT-NC	Averaging Time - Non-Cancer	2,190	days	EPA 1989	
	Commercial Worker	Adult	Indoor Air	CA	Chemical Concentration in Air	EPC	mg/m^3	Modeled (see Appendix D)	Intake (mg/kg-day) =
				InhR	Inhalation Rate	0.83	$m^3/hour$	EPA 1991	(CA x InhR x ET x EF x ED) / (BW x AT)
				ET	Exposure Time	8	hours/day	EPA 1991	
				EF	Exposure Frequency	250	days/year	EPA 1991	
				ED	Exposure Duration	25	years	EPA 1991	
				BW	Body Weight	70	kg	EPA 1991	
				AT-C	Averaging Time - Cancer	25,550	days	EPA 1989	
				AT-NC	Averaging Time - Non-Cancer	9,125	days	EPA 1989	

Notes:
(1) See Section 2.2 for discussion of the intake assumptions.

Definitions:
days/year = Days per year
hours/day = Hours per day
kg = Kilogram
EPC = Exposure point concentration (for each well) shown in Table 2
mg/m^3 = Milligram per cubic meter
$m^3/hour$ = Cubic meter per hour

References:
U.S. Environmental Protection Agency (EPA). 1989. "Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A)." Office of Emergency and Remedial Response. Washington, DC. December.
EPA 1991. "Interoffice Memorandum Regarding Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors." From T. Fields, Jr. and B. Diamond. To Director, Waste Management Division, Regions 1, 4, 5, and 7; Director, Emergency and Remedial Response Division, Region 3; Director, Hazardous Waste Management Division, Regions 3, 6, 8, and 9; Director, Hazardous Waste Division, Region 10. March 25.
EPA. 1997. "Exposure Factors Handbook, Volume 1-General Factors." Office of Research and Development. National Center for Environmental Assessment. Washington, DC. August.

TABLE A-5
NONCANCER TOXICITY DATA - INHALATION
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

Chemical of Potential Concern	Chronic/ Subchronic	Inhalation RfC		Extrapolated RfD		Primary Target Organ(s)	Combined Uncertainty/Modifying Factors	RfC : Target Organ(s)	
		Value	Units	Value	Units			Source(s)	Date(s) (MM/DD/YYYY)
BENZENE	Chronic	3.0E-02	mg/m^3	8.6E-03	mg/kg-day	Blood	300	IRIS	6/29/2005
TOLUENE	Chronic	5.0E+00	mg/m^3	1.4E+00	mg/kg-day	CNS	10	IRIS	9/23/2005
XYLENE	Chronic	1.0E-01	mg/m^3	2.9E-02	mg/kg-day	CNS	300	IRIS	4/24/2008
TPH-Gasoline	Chronic	9.4E+00	mg/m^3	2.7E+00	mg/kg-day	Neurological, Liver, Kidney	NA	TPHCWG 1997	

Definitions:
CNS = Central nervous system
EPA = U.S. Environmental Protection Agency
mg/m^3 = Milligram per cubic meter
NA = Not applicable
RfC = Reference concentration
RfD = Reference dose

References:

IRIS = EPA. 2009. Integrated Risk Information System. Online Database. Available at http://www.epa.gov/iris. Accessed August 17.
TPHCWG. 1997. Development of Fraction-Specific Reference Doses and Reference Concentrations for Total Petroleum Hydrocarbons.

TABLE A-6
CANCER TOXICITY DATA - INHALATION
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

Chemical of Potential Concern	Unit Risk		Inhalation Cancer Slope Factor		Weight of Evidence/ Cancer Guideline Description	Unit Risk : Inhalation CSF	
	Value	Units	Value	Units		Source(s)	Date(s) (MM/DD/YYYY)
BENZENE	7.8E-06	$(ug/m^3)^{-1}$	2.7E-02	$(mg/kg\text{-}day)^{-1}$	A	IRIS	6/29/2005
TOLUENE	--	--	--	--	D	IRIS	9/25/2005
XYLENE	--	--	--	--	D	IRIS	4/24/2008
TPH - Gasoline	--	--	--	--	--	--	--

Definitions:
-- = Not available; not applicable
A = Known human carcinogen (EPA 2008)
CSF = Cancer slope factor
D = Data inadequate to assess carcinogenicity (EPA 2009)
EPA = U.S. Environmental Protection Agency
IRIS = Integrated Risk Information System (EPA 2009)

References:

EPA. 2004. Region 9 PRG Table. Online Table. Available at http://www.epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf. Accessed April 30.
EPA. 2009. Integrated Risk Information System. Online Database. Available at http://www.epa.gov/iris. Accessed August 17.

TABLE A-7.1.RME
CALCULATION OF CHEMICAL CANCER RISKS AND NONCANCER HAZARDS: ADULT RESIDENT
REASONABLE MAXIMUM EXPOSURE
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Quotient				
					Value	Units	Intake (Dose)		CSF/Unit Risk		Cancer Risk	Intake (Dose)		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Vapors	Indoor Air	Inhalation	BENZENE	3.5E-02	ug/m³	3.3E-06	mg/kg-day	2.7E-02	1/mg/kg-day	9.0E-08	9.7E-06	mg/kg-day	8.6E-03	mg/kg-day	1.1E-03
		Locations of		TOLUENE	1.4E-01	ug/m³	1.3E-05	mg/kg-day	--	--	--	3.8E-05	mg/kg-day	1.4E+00	mg/kg-day	2.7E-05
		Maximum		XYLENE	3.0E-02	ug/m³	2.8E-06	mg/kg-day	--	--	--	8.1E-06	mg/kg-day	2.9E-02	mg/kg-day	2.8E-04
		Detections		TPH-gasoline	3.3E+00	ug/m³	3.1E-04	mg/kg-day	--	--	--	8.9E-04	mg/kg-day	2.7E+00	mg/kg-day	3.3E-04
			Exp. Route Total								9.0E-08					1.8E-03

Notes:

--	Not available or not applicable	EPC	Exposure point concentration	mg/kg-day	Milligram per kilogram per day	RfC	Reference concentration
CSF	Cancer slope factor	mg/kg	Milligram per kilogram	RAGS	Risk Assessment Guidance for Superfund	RME	Reasonable maximum exposure
EPA	U.S. Environmental Protection Agency			RfD	Reference dose	ug/m³	Microgram per cubic meter

TABLE A-7.1.RME
CALCULATION OF CHEMICAL CANCER RISKS AND NONCANCER HAZARDS: ADULT CHILD
REASONABLE MAXIMUM EXPOSURE
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

Scenario Timeframe:	Future
Receptor Population:	Resident
Receptor Age:	Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Quotient				
					Value	Units	Intake (Dose)		CSF/Unit Risk		Cancer Risk	Intake (Dose)		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Vapors	Indoor Air Locations of Maximum Detections	Inhalation	BENZENE	3.5E-02	ug/m³	2.0E-06	mg/kg-day	2.7E-02	1/mg/kg-day	5.3E-08	2.3E-05	mg/kg-day	8.6E-03	mg/kg-day	2.7E-03
				TOLUENE	1.4E-01	ug/m³	7.7E-06	mg/kg-day	--	--	--	9.0E-05	mg/kg-day	1.4E+00	mg/kg-day	6.3E-05
				XYLENE	3.0E-02	ug/m³	1.6E-06	mg/kg-day	--	--	--	1.9E-05	mg/kg-day	2.9E-02	mg/kg-day	6.7E-04
				TPH-gasoline	3.3E+00	ug/m³	1.8E-04	mg/kg-day	--	--	--	2.1E-03	mg/kg-day	2.7E+00	mg/kg-day	7.8E-04
			Exp. Route Total								5.3E-08					4.2E-03

Notes:

--	Not available or not applicable	EPC	Exposure point concentration	mg/kg-day	Milligram per kilogram per day	RfC	Reference concentration
CSF	Cancer slope factor	mg/kg	Milligram per kilogram	RAGS	Risk Assessment Guidance for Superfund	RME	Reasonable maximum exposure
EPA	U.S. Environmental Protection Agency			RfD	Reference dose	ug/m³	Microgram per cubic meter

TABLE A-7.1.RME
CALCULATION OF CHEMICAL CANCER RISKS AND NONCANCER HAZARDS: ADULT COMMERCIAL WORKER
REASONABLE MAXIMUM EXPOSURE
AVIS / NATIONAL / PAYLESS COMMINGLED GROUNDWATER PLUME AREA

Scenario Timeframe:	Current and Future
Receptor Population:	Commercial Worker
Receptor Age:	Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Quotient				
					Value	Units	Intake (Dose)		CSF/Unit Risk		Cancer Risk	Intake (Dose)		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Vapors	Indoor Air Locations of Maximum Detections	Inhalation	BENZENE	3.5E-02	ug/m³	8.2E-07	mg/kg-day	2.7E-02	1/mg/kg-day	2.3E-08	2.3E-06	mg/kg-day	8.6E-03	mg/kg-day	2.7E-04
				TOLUENE	1.4E-01	ug/m³	3.3E-06	mg/kg-day	--	--	--	9.1E-06	mg/kg-day	1.4E+00	mg/kg-day	6.4E-06
				XYLENE	3.0E-02	ug/m³	6.9E-07	mg/kg-day	--	--	--	1.9E-06	mg/kg-day	2.9E-02	mg/kg-day	6.8E-05
				TPH-gasoline	3.3E+00	ug/m³	7.6E-05	mg/kg-day	--	--	--	2.1E-04	mg/kg-day	2.7E+00	mg/kg-day	7.9E-05
			Exp. Route Total								2.3E-08					4.2E-04

Notes:

--	Not available or not applicable	EPC	Exposure point concentration	mg/kg-day	Milligram per kilogram per day	RfC	Reference concentration
CSF	Cancer slope factor	mg/kg	Milligram per kilogram	RAGS	Risk Assessment Guidance for Superfund	RME	Reasonable maximum exposure
EPA	U.S. Environmental Protection Agency			RfD	Reference dose	ug/m³	Microgram per cubic meter

APPENDIX B

Subsurface Information from Soil Gas Well Installations

PTS Laboratories

PTS File No: 39528
Client: Broadbent & Associates, Inc.

PHYSICAL PROPERTIES DATA - VAPOR TRANSPORT PACKAGE

PROJECT NAME: Avis Soil Gas Survey
PROJECT NO: 95-01-150

		METHODOLOGY:	API RP40/ASTM D2216		API RP40		API RP40	API RP40		Mod. ASTM D425	API RP40	WALKLEY-BLACK	
							POROSITY (2)						
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	MOISTURE CONTENT, % weight	MOISTURE CONTENT, cm^3/cm^3	DENSITY DRY BULK, g/cm^3	DENSITY GRAIN, g/cm^3	TOTAL, cm^3/cm^3	AIR FILLED, cm^3/cm^3	WATER FILLED, cm^3/cm^3	EFFECTIVE, cm^3/cm^3	TOTAL PORE FLUID (3) SATURATIONS, % Pv	TOTAL ORGANIC CARBON, mg/kg	FRACTION ORGANIC CARBON, g/g
HJMW-22-8'	8	V	21.7	0.341	1.57	2.64	0.405	0.064	0.341	0.158	84.3	590	5.90E-04
OMW-36-8'-4½'	4.5	V	9.0	0.181	2.01	2.71	0.256	0.075	0.181	0.136	70.8	1300	1.30E-03
OMW-36-8'-7'	7	V	10.3	0.195	1.90	2.65	0.284	0.089	0.195	0.147	68.7	590	5.90E-04
OMW-36-5'	5	V	5.5	0.109	1.99	2.67	0.255	0.145	0.109	0.141	43.0	1250	1.25E-03
OMW-43-8'-4½'	4.5	V	9.4	0.170	1.81	2.63	0.310	0.139	0.170	0.215	55.0	550	5.50E-04

(1) Sample Orientation: H = horizontal; V = vertical
(2) Total Porosity = no pore fluids in place; all Interconnected pore channels; Air Filled = pore channels not occupied by pore fluids, native sample; Effective = drainage porosity
(3) Water = 0.9996 g/cc; Pv = Pore Volume; ND = Not Detected

PTS File No: 39528
Client: Broadbent & Associates, Inc.

PERMEABILITY DATA - VAPOR TRANSPORT PACKAGE

PROJECT NAME: Avis Soil Gas Survey
PROJECT NO: 95-01-150

		METHODOLOGY:	API RP40		API RP40 / EPA 9100		
			25 PSI CONFINING PRESSURE		25 PSI CONFINING PRESSURE		
SAMPLE ID.	DEPTH, ft.	SAMPLE ORIENTATION (1)	EFFECTIVE PERMEABILITY TO AIR (2), millidarcy	SPECIFIC PERMEABILITY TO AIR (3), millidarcy	SPECIFIC PERMEABILITY TO WATER (4), millidarcy	HYDRAULIC CONDUCTIVITY (4), cm/s	INTRINSIC PERMEABILITY TO WATER (4), cm^2
HJMW-22-8'	8	V	4.40	98.5	1.11	1.09E-06	1.10E-11
OMW-36-8'-4½'	4.5	V	443	820	1.44	1.41E-06	1.42E-11
OMW-36-8'-7'	7	V	572	955	26.7	2.61E-05	2.64E-10
OMW-36-5'	5	V	1586	1911	20.2	1.97E-05	1.99E-10
OMW-43-8'-4½'	4.5	V	133	218	4.43	4.31E-06	4.37E-11

(1) Sample Orientation: H = horizontal, V = vertical, R = remold
(2) Native State = As received with pore fluids in place
(3) Specific = without moisture
(4) Permeability to water and conductivity measured at saturated conditions

PTS File No: 39528
Client: Broadbent & Associates, Inc.

SOIL CLASSIFICATION DATA - VAPOR TRANSPORT PACKAGE

PROJECT NAME: Avis Soil Gas Survey
PROJECT NO: 95-01-150

METHODS:		ASTM D4318			ASTM D4318	ASTM D2487	USDA
		ATTERBERG LIMITS (1)			USCS / PLASTICITY CHART SYMBOL (Fines: <#40 Sieve)	USCS CLASSIFICATION, Group Symbol: Name	USDA/SCS (2) SOIL TEXTURE SCHEME
SAMPLE ID.	DEPTH, ft.	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX			
HJMW-22-8'	8	71.6	29.6	42.0	CH	SC: Clayey sand	Sand
OMW-36-8'-4½'	4.5	17.9	11.2	6.7	CL	GW: Well graded gravel with sand	Sand
OMW-36-8'-7'	7	22.8	13.0	9.8	CL	SC: Clayey sand	Sandy loam
OMW-36-5'	5	15.8	11.8	4.0	CL	GW: Well graded gravel with sand	Sand
OMW-43-8'-4½'	4.5	17.0	12.0	5.0	CL	GW-GC: Well graded gravel with clay and sand	Sand

USCS: Unified Soil Classification System
USDA: US Department of Agriculture
SCS: Soil Conservation Service

(1) Silt assumed as fine fraction for NON-PLASTIC (NP) samples. (2) Sand considered to be >No. 200 sieve for USDA SOIL TEXTURE SCHEME.

APPENDIX C

Johnson & Ettinger Modeling (Sand Default)

TABLE C-1
Groundwater to Indoor Air Modeling Using the Johnson & Ettinger Model
Using Various Data Sets (as described in text)

Soil Exposure Scenario

Scenario Timeframe: Future
Medium: Subsurface Vapors
Exposure Medium: Vapors in Indoor Air
Exposure Point: Inhalation Indoors

Model Assumption	Value	Units	Basis
Depth below grade to bottom of enclosed floor space	15	cm	Default
Average soil temperature	10	degrees C	Estimated average for Nevada desert
Stratum SCS soil type	S	unitless	Sand
Stratum soil dry bulk density	1.66	(g/cm^3)	Based on sand*
Stratum soil total porosity	0.375	unitless	Based on sand*
Stratum soil water-filled porosity	0.054	unitless	Based on sand*
Soil Organic Carbon Fraction	0.002	unitless	Based on sand*
Enclosed space height	366	cm	Default
Indoor air exchange rate	0.25	per hr	Default
Average vapor flowrate into buildng	5	L/min	Default
Depth to soil gas sample location	152.5	cm	Assuming 5 feet bgs for all chemicals (most shallow depth)
Surrogate chemical for modeling gasoline fraction	Hexane		

*For maximum conservatism, the model's defaults for sand were applied as these consider the most porous option among the site-specific variations. See Appendix B. Site-specific values are up to 10 times less conservative, so risks should be overestimated assumng sand.

Input EPC (in ug/m^3) Based on Data Assumptions Discussed in Text and Data Shown in Table 1

SCS Soil Type Assigned	Max Detected Concentration S
Benzene	13
Toluene	52
Xylenes	11
TPH - Gasoline Fraction (Hexane)	900.0

Output Concentrations are in (ug/m^3) Using SG-Screen Version 3.1 (02/04)

	Modeled Concentration
Benzene	0.0354
Toluene	0.14
Xylenes	0.0298
TPH - Gasoline Fraction (Hexane)	3.3

SG-SCREEN
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
71432	1.30E+01			Benzene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	152.5	10	S		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
S	1.66	0.375	0.054	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Unit risk factor, URF ($\mu g/m^3$)$^{-1}$	Reference conc., RfC (mg/m^3)	Molecular weight, MW (g/mol)
8.80E-02	9.80E-06	5.54E-03	25	7,342	353.24	562.16	7.8E-06	3.0E-02	78.11

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm³/cm³)	Vadose zone effective total fluid saturation, S_{te} (cm³/cm³)	Vadose zone soil intrinsic permeability, k_i (cm²)	Vadose zone soil relative air permeability, k_{rg} (cm²)	Vadose zone soil effective vapor permeability, k_v (cm²)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. (μg/m³)	Bldg. ventilation rate, $Q_{building}$ (cm³/s)
137.5	0.321	0.003	9.92E-08	0.998	9.91E-08	4,000	1.30E+01	1.69E+04

Area of enclosed space below grade, A_B (cm²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m³/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm²/s)	Diffusion path length, L_d (cm)
1.00E+06	5.00E-03	15	8,122	2.68E-03	1.15E-01	1.75E-04	1.42E-02	137.5

Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m³)
15	1.30E+01	1.25	8.33E+01	1.42E-02	5.00E+03	1.22E+05	2.72E-03	3.54E-02

Unit risk factor, URF (μg/m³)⁻¹	Reference conc., RfC (mg/m³)
7.8E-06	3.0E-02

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.1E-07	1.1E-03

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET

SG-SCREEN
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m³)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
108883	5.20E+01			Toluene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm²)
15	152.5	10	S		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm³)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm³/cm³)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
S	1.66	0.375	0.054	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Molecular weight, MW (g/mol)
8.70E-02	8.60E-06	6.62E-03	25	7,930	383.78	591.79	0.0E+00	4.0E-01	92.14

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
137.5	0.321	0.003	9.92E-08	0.998	9.91E-08	4,000	5.20E+01	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	5.00E-03	15	9,154	2.92E-03	1.26E-01	1.75E-04	1.41E-02	137.5

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)
15	5.20E+01	1.25	8.33E+01	1.41E-02	5.00E+03	1.40E+05	2.71E-03	1.41E-01

Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
NA	4.0E-01

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	3.4E-04

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET

SG-SCREEN
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m³)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
95476	1.10E+01			o-Xylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm²)
15	152.5	10	S		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm³)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm³/cm³)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
S	1.66	0.375	0.054	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Molecular weight, MW (g/mol)
8.70E-02	1.00E-05	5.18E-03	25	8,661	417.60	630.30	0.0E+00.	1.0E-01	106.17

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
137.5	0.321	0.003	9.92E-08	0.998	9.91E-08	4,000	1.10E+01	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	5.00E-03	15	10,404	2.04E-03	8.79E-02	1.75E-04	1.41E-02	137.5

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)
15	1.10E+01	1.25	8.33E+01	1.41E-02	5.00E+03	1.40E+05	2.71E-03	2.98E-02

Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)
NA	1.0E-01

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	2.9E-04

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET

SG-SCREEN
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
110543	9.00E+02			Hexane

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	152.5	10	S		

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
S	1.66	0.375	0.054	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H (atm-m^3/mol)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Unit risk factor, URF (μg/m^3)$^{-1}$	Reference conc., RfC (mg/m^3)	Molecular weight, MW (g/mol)
2.00E-01	7.77E-06	1.66E+00	25	6,895	341.70	508.00	0.0E+00	2.0E-01	86.18

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm³/cm³)	Vadose zone effective total fluid saturation, S_{te} (cm³/cm³)	Vadose zone soil intrinsic permeability, k_i (cm²)	Vadose zone soil relative air permeability, k_{rg} (cm²)	Vadose zone soil effective vapor permeability, k_v (cm²)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. (μg/m³)	Bldg. ventilation rate, $Q_{building}$ (cm³/s)
137.5	0.321	0.003	9.92E-08	0.998	9.91E-08	4,000	9.00E+02	1.69E+04

Area of enclosed space below grade, A_B (cm²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m³/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm²/s)	Diffusion path length, L_d (cm)
1.00E+06	5.00E-03	15	7,737	8.32E-01	3.58E+01	1.75E-04	3.23E-02	137.5

Convection path length, L_p (cm)	Source vapor conc., C_{source} (μg/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (μg/m³)
15	9.00E+02	1.25	8.33E+01	3.23E-02	5.00E+03	1.73E+02	3.65E-03	3.28E+00

Unit risk factor, URF (μg/m³)⁻¹	Reference conc., RfC (mg/m³)
NA	2.0E-01

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	1.6E-02

MESSAGE SUMMARY BELOW:

END

APPENDIX D

Johnson & Ettinger Modeling (Site-Specific Comparison)

Table D-1

Data Comparison -- Sand Default vs Measured Physical Soil Parameters

Model Parameters	EPA Johnson & Ettinger Soil Gas Model Inputs				
Condition	"Sand" Default Conditions (all wells)	Measured and Calculated Values (HJMW-22)	Measured and Calculated Values (OMW-43)	Units	Comments
Stratum SCS soil type	Sand	NA	NA	unitless	Default value
Entered Effective Permeability to Air	Default (9.91E-08)	4.34E-11	1.31E-09	cm^2	Converted from millidarcies (# mD * 9.86923E-12; HJMW-22 = 4.4mD; OMW-43 = 133 mD)
Stratum soil dry bulk density	1.66	1.57	1.81	(g/cm^3)	
Stratum soil total porosity	0.375	0.405	0.31	unitless	
Stratum soil water-filled porosity	0.054	0.341	0.17	unitless	
Compounds	Modeled Indoor Air Concentration				
Benzene	0.0354	0.000395		(ug/m^3)	Modeled from measured concentration in HJMW-22
Toluene	0.14	0.0015		(ug/m^3)	Modeled from measured concentration in HJMW-22
Xylenes	0.0298	0.000354		(ug/m^3)	Modeled from measured concentration in HJMW-22
TPH-GRO (Hexane)	3.27		0.915	(ug/m^3)	Modeled from measured concentration in OMW-43

DATA ENTRY SHEET

SG-SCREEN
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
71432	1.30E+01			Benzene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	152.5	10			4.34E-11

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
	1.57	0.405	0.341	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Molecular weight, MW (g/mol)
8.80E-02	9.80E-06	5.54E-03	25	7,342	353.24	562.16	7.8E-06	3.0E-02	78.11

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
137.5	0.064	#N/A	#N/A	#N/A	4.34E-11	4,000	1.30E+01	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	5.00E-03	15	8,122	2.68E-03	1.15E-01	1.75E-04	7.12E-05	137.5

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)
15	1.30E+01	1.25	8.33E+01	7.12E-05	5.00E+03	#NUM!	3.04E-05	3.95E-04

Unit risk factor, URF ($\mu g/m^3$)$^{-1}$	Reference conc., RfC (mg/m^3)
7.8E-06	3.0E-02

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
1.3E-09	1.3E-05

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET

SG-SCREEN
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g ($\mu g/m^3$)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
108883	5.20E+01			Toluene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm^2)
15	152.5	10			4.34E-11

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm^3)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm^3/cm^3)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
	1.57	0.405	0.341	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Unit risk factor, URF $(\mu g/m^3)^{-1}$	Reference conc., RfC (mg/m^3)	Molecular weight, MW (g/mol)
8.70E-02	8.60E-06	6.62E-03	25	7,930	383.78	591.79	0.0E+00	4.0E-01	92.14

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
137.5	0.064	#N/A	#N/A	#N/A	4.34E-11	4,000	5.20E+01	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m^3/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	5.00E-03	15	9,154	2.92E-03	1.26E-01	1.75E-04	6.77E-05	137.5

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)
15	5.20E+01	1.25	8.33E+01	6.77E-05	5.00E+03	#NUM!	2.89E-05	1.50E-03

Unit risk factor, URF ($\mu g/m^3$)$^{-1}$	Reference conc., RfC (mg/m^3)
NA	4.0E-01

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	3.6E-06

MESSAGE SUMMARY BELOW:

END

DATA ENTRY SHEET

SG-SCREEN
Version 3.1; 02/04

Reset to Defaults

Soil Gas Concentration Data

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m³)	OR	ENTER Soil gas conc., C_g (ppmv)	Chemical
95476	1.10E+01			o-Xylene

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)	OR	ENTER User-defined vadose zone soil vapor permeability, k_v (cm²)
15	152.5	10			4.34E-11

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm³)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm³/cm³)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
	1.57	0.405	0.341	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Molecular weight, MW (g/mol)
8.70E-02	1.00E-05	5.18E-03	25	8,661	417.60	630.30	0.0E+00	1.0E-01	106.17

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm³/cm³)	Vadose zone effective total fluid saturation, S_{te} (cm³/cm³)	Vadose zone soil intrinsic permeability, k_i (cm²)	Vadose zone soil relative air permeability, k_{rg} (cm²)	Vadose zone soil effective vapor permeability, k_v (cm²)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. (µg/m³)	Bldg. ventilation rate, $Q_{building}$ (cm³/s)
137.5	0.064	#N/A	#N/A	#N/A	4.34E-11	4,000	1.10E+01	1.69E+04

Area of enclosed space below grade, A_B (cm²)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} (atm-m³/mol)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm²/s)	Diffusion path length, L_d (cm)
1.00E+06	5.00E-03	15	10,404	2.04E-03	8.79E-02	1.75E-04	7.54E-05	137.5

Convection path length, L_p (cm)	Source vapor conc., C_{source} (µg/m³)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm³/s)	Crack effective diffusion coefficient, D^{crack} (cm²/s)	Area of crack, A_{crack} (cm²)	Exponent of equivalent foundation Peclet number, $exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ (µg/m³)
15	1.10E+01	1.25	8.33E+01	7.54E-05	5.00E+03	#NUM!	3.22E-05	3.54E-04

Unit risk factor, URF (µg/m³)⁻¹	Reference conc., RfC (mg/m³)
NA	1.0E-01

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	3.4E-06

MESSAGE SUMMARY BELOW:

END

SG-SCREEN
Version 3.1; 02/04

Reset to Defaults

ENTER Chemical CAS No. (numbers only, no dashes)	ENTER Soil gas conc., C_g (μg/m³)		ENTER Soil gas conc., C_g (ppmv)	Chemical
	Soil Gas Concentration Data	OR		
110543	9.00E+02			Hexane

MORE ↓

ENTER Depth below grade to bottom of enclosed space floor, L_F (15 or 200 cm)	ENTER Soil gas sampling depth below grade, L_s (cm)	ENTER Average soil temperature, T_S (°C)	ENTER Vadose zone SCS soil type (used to estimate soil vapor permeability)		ENTER User-defined vadose zone soil vapor permeability, k_v (cm²)
15	152.5	10		OR	1.31E-09

MORE ↓

ENTER Vandose zone SCS soil type (Lookup Soil Parameters)	ENTER Vadose zone soil dry bulk density, ρ_b^A (g/cm³)	ENTER Vadose zone soil total porosity, n^V (unitless)	ENTER Vadose zone soil water-filled porosity, θ_w^V (cm³/cm³)	ENTER Average vapor flow rate into bldg. (Leave blank to calculate) Q_{soil} (L/m)
	1.81	0.31	0.17	5

MORE ↓

ENTER Averaging time for carcinogens, AT_C (yrs)	ENTER Averaging time for noncarcinogens, AT_{NC} (yrs)	ENTER Exposure duration, ED (yrs)	ENTER Exposure frequency, EF (days/yr)
70	30	30	350

END

CHEMICAL PROPERTIES SHEET

Diffusivity in air, D_a (cm^2/s)	Diffusivity in water, D_w (cm^2/s)	Henry's law constant at reference temperature, H ($atm\text{-}m^3/mol$)	Henry's law constant reference temperature, T_R (°C)	Enthalpy of vaporization at the normal boiling point, $\Delta H_{v,b}$ (cal/mol)	Normal boiling point, T_B (°K)	Critical temperature, T_C (°K)	Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)	Molecular weight, MW (g/mol)
2.00E-01	7.77E-06	1.66E+00	25	6,895	341.70	508.00	0.0E+00	2.0E-01	86.18

END

INTERMEDIATE CALCULATIONS SHEET

Source-building separation, L_T (cm)	Vadose zone soil air-filled porosity, θ_a^V (cm^3/cm^3)	Vadose zone effective total fluid saturation, S_{te} (cm^3/cm^3)	Vadose zone soil intrinsic permeability, k_i (cm^2)	Vadose zone soil relative air permeability, k_{rg} (cm^2)	Vadose zone soil effective vapor permeability, k_v (cm^2)	Floor-wall seam perimeter, X_{crack} (cm)	Soil gas conc. ($\mu g/m^3$)	Bldg. ventilation rate, $Q_{building}$ (cm^3/s)
137.5	0.140	#N/A	#N/A	#N/A	1.31E-09	4,000	9.00E+02	1.69E+04

Area of enclosed space below grade, A_B (cm^2)	Crack-to-total area ratio, η (unitless)	Crack depth below grade, Z_{crack} (cm)	Enthalpy of vaporization at ave. soil temperature, $\Delta H_{v,TS}$ (cal/mol)	Henry's law constant at ave. soil temperature, H_{TS} ($atm\text{-}m^3/mol$)	Henry's law constant at ave. soil temperature, H'_{TS} (unitless)	Vapor viscosity at ave. soil temperature, μ_{TS} (g/cm-s)	Vadose zone effective diffusion coefficient, D^{eff}_V (cm^2/s)	Diffusion path length, L_d (cm)
1.00E+06	5.00E-03	15	7,737	8.32E-01	3.58E+01	1.75E-04	2.98E-03	137.5

Convection path length, L_p (cm)	Source vapor conc., C_{source} ($\mu g/m^3$)	Crack radius, r_{crack} (cm)	Average vapor flow rate into bldg., Q_{soil} (cm^3/s)	Crack effective diffusion coefficient, D^{crack} (cm^2/s)	Area of crack, A_{crack} (cm^2)	Exponent of equivalent foundation Peclet number, $\exp(Pe^f)$ (unitless)	Infinite source indoor attenuation coefficient, α (unitless)	Infinite source bldg. conc., $C_{building}$ ($\mu g/m^3$)
15	9.00E+02	1.25	8.33E+01	2.98E-03	5.00E+03	1.78E+24	1.02E-03	9.15E-01

Unit risk factor, URF ($(\mu g/m^3)^{-1}$)	Reference conc., RfC (mg/m^3)
NA	2.0E-01

END

RESULTS SHEET

INCREMENTAL RISK CALCULATIONS:

Incremental risk from vapor intrusion to indoor air, carcinogen (unitless)	Hazard quotient from vapor intrusion to indoor air, noncarcinogen (unitless)
NA	4.4E-03

MESSAGE SUMMARY BELOW:

END