integral consulting inc.

DRAFT
RISK ASSESSMENT WORK PLAN

Former Montrose and Stauffer Facilities
Henderson, Nevada

Prepared for
Montrose Chemical Corporation of California
Stauffer Management Company LLC
Syngenta Crop Protection, Inc.
Olin Corporation

Prepared by
Integral Consulting Inc.
2661 Riva Road, Bldg 500
Suite 520
Annapolis, MD 21401

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ACRONYMS AND ABBREVIATIONS

ABS_{GI}	fraction of contaminant absorbed in gastrointestinal tract
ACD	Agricultural Chemical Division
ACF	area correction factor
ADD	average daily dose
ALM	adult lead methodology
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
BaP	benzo(a)pyrene
BCL	basic comparison level
bgs	below ground surface
BHC	benzene hexachloride
BMI	Black Mountain Industrial
BRC	Basic Remediation Company
BSA	benzenesulfonic acid
BW	body weight
Cal/EPA	California Environmental Protection Agency
COPC	constituent of potential concern
CSF	cancer slope factor
CSM	conceptual site model
CTE	central tendency exposure
DAD	daily average dose
DCBP	dichlorobenzophenone
DEPT	diethyl phosphorodithoic acid
DMPT	dimethyl phosphorodithoic acid
EC	exposure concentration
ED	exposure duration
EF	exposure frequency
EPA	U.S. Environmental Protection Agency

EPC	exposure point concentration
GI	gastrointestinal tract
GSF	gamma shielding factor
HCL	hydrochloric acid
HEAST	Health Effects Assessment Summary Tables
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
Integral	Integral Consulting Inc.
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
LADD	lifetime average daily dose
LOAEL	lowest-observed-adverse-effects level
MDA	minimum detectable activity
MDL	method detection limit
Montrose	Montrose Chemical Company of California
MRL	minimal risk level
NDEP	Nevada Division of Environmental Protection
NHANES	National Health and Nutrition Examination Survey
NOAEL	no-observed-adverse-effects level
Olin	Olin Corporation
ORNL	Oak Ridge National Laboratory
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PbB_0	baseline blood lead level
pCBSA	4-chlorobenzene sulfonic acid
PCDD	polychlorinated dibenzo-*p*-dioxin
PCDF	polychlorinated dibenzofuran
pCi	pico Curie
PEF	particulate emission factor

Pioneer	Pioneer Americas, LLC
PPRTV	provisional peer reviewed toxicity values
PRG	preliminary remediation goal
QC	quality control
RAGS	Risk Assessment Guidance for Superfund
RAIS	Risk Assessment Information System
RAS	remedial alternatives study
RAWP	risk assessment work plan
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RME	reasonable maximum exposure
RPF	relative potency factor
SE	secular equilibrium
SMC	Stauffer Management Company LLC
SQL	sample quantitation limit
SRC	site-related chemical
Stauffer	Stauffer Chemical Company
SVOC	semivolatile organic compound
Syngenta	Syngenta Crop Protection, Inc.
TCDD	tetrachlorodibenzo-*p*-dioxin
TEF	toxic equivalency factor
TEQ	toxic equivalent
TEM	transmission electron microscopy
TIC	tentatively identified compound
Timet	Titanium Metals Corporation
TPH	total petroleum hydrocarbon
Tronox	Tronox, Inc.
UCL	upper confidence limit
VF	volatilization factor

VOC	volatile organic compound
WHO	World Health Organization
WOE	weight-of-evidence

1 INTRODUCTION

This risk assessment work plan (RAWP) outlines the proposed approach for assessing potential human health risks at the former Montrose and Stauffer facilities in Henderson, Nevada (the Site). This RAWP has been prepared on behalf of Montrose Chemical Company of California (Montrose), Stauffer Management Company LLC/Syngenta Crop Protection, Inc. (SMC/Syngenta) and Olin Corporation (Olin) (the Companies) as part of the overall effort to characterize the nature and extent of contamination at this former facility and determine the need for and effectiveness of remedial actions to address overall risks.

1.1 SITE DESCRIPTION[1]

The former Montrose and Stauffer facilities are located in the southwest portion of a heavily industrialized area currently referred to as the Black Mountain Industrial (BMI) Complex. The BMI Complex is located within an unincorporated portion of Clark County surrounded by the City of Henderson, NV. Under current operations, the BMI Complex includes property owned, leased, or administered by Olin (and formerly Pioneer Americas LLC [Pioneer]), Tronox, Inc. (Tronox), Titanium Metals Corporation (Timet), Chemstar Lime Company, and Basic Remediation Company (BRC) and its affiliates (Figure 1-1). The Site, as referred to in this work plan, comprises the portion of the BMI complex previously utilized by Montrose and Stauffer Chemical Company (Stauffer) and currently owned and operated by Olin for the production of liquid chlorine, caustic soda, hydrochloric acid (HCL), and bleach (Figure 1-2).

1.1.1 Site Setting

The Site is located within the Las Vegas Valley and the southwestern part of the Basin and Range physiographic province. The climate is arid with precipitation averaging slightly less than 4.5 inches per year (NOAA 2009). Winters are mild and summers are hot with temperatures often above 100 degrees Fahrenheit (°F). The average annual temperatures range from a low of approximately 56°F to a high of approximately 80°F (NOAA 2009).

Land surface at the Site is a mixture of natural and non-native materials. Some portions of the Site are paved. Outside of these areas, most of the land surface is bare soil or sparsely vegetated. Surface and near-surface soils at the Site are generally coarse-grained, comprised of quaternary alluvium deposits consisting of sands and gravels, with varying amounts of silts and occasional cobbles (Hargis 2008). In some areas, caliche is present on the surface (PES 2006, 2007a).

[1] The information summarized in this section is largely excerpted from previous reports prepared by PES (2006, 2007a) and Hargis (2008).

Natural site drainage is to the north, but no perennially wet drainages or other natural water bodies exist on Site. Wind direction is variable, but predominately from the northwest, south, southwest, and southeast (Figure 1-3).

The Site is currently used exclusively for industrial processes. Site access to Olin's current operating facility is controlled by gates and a guard house. A 6-ft high chain-linked razor wire-topped perimeter fence exits around portions of the Site.

Areas immediately adjacent to the Site are undeveloped or industrial/commercial. The nearest residences occur to the west-northwest, south, and southeast and are located more than one-half mile from the Site.

1.1.2 Site History

The Site was first developed as part of the original BMI Complex, which was constructed under a contract with the U.S. Defense Plant Corporation and operated by BMI to produce magnesium for the World War II effort from 1942 through 1944. Chlorine was essential to magnesium production and a chlorine and caustic soda plant was constructed at the Site (PES 2006).

From 1945 through 1984, the Site was operated by Stauffer for production of chlorine, sodium hydroxide, HCL, and agricultural chemical products (PES 2006). The most extensive operations included the manufacture of chlorine and caustic soda from 1945 through 1984, and the production of HCL from 1954 to 1984. Stauffer also manufactured the pesticides trithion (1958 through 1984), imidan (1964 through 1982), parachlorothiophenol (1960 through 1984), and thiophenol (1967 through 1982) at its Agricultural Chemical Division (ACD) Plant. Lindane (gamma-benzene hexachloride [BHC]) was produced at the former Lindane Plant from 1946 through 1958. The Stauffer manufacturing facilities were largely demolished in 1984.

Montrose constructed and operated a manufacturing plant to produce a variety of organic chemicals from 1947 through 1983 (Hargis 2008). Organic chemical products included chlorobenzene, polychlorinated benzenes, chloral, and 4, 4-dichlorobenzil. Montrose ceased operations at the organic chemical plant in 1983 and demolished the plant in 1984. Montrose also constructed a manufacturing plant for the production of synthetic HCL in 1954 and at an expanded facility constructed in 1977 (Hargis 2008). Montrose produced HCL at these production facilities until 1985.

Olin currently operates chlor alkali production facilities at the Site and manufactures liquid chlorine, caustic soda, HCL, and bleach. Olin began operation in 2007 when they acquired Pioneer.

1.2 SCOPE AND FOCUS OF THE HUMAN HEALTH RISK ASSESSMENT

This document has been prepared to satisfy the Nevada Division of Environmental Protection (NDEP) requirements to provide a RAWP detailing the human health risk assessment (HHRA) methodology as part of the overall remedial alternatives studies (RAS) to be conducted at the Site (NDEP 2008a). As outlined by NDEP, remedial alternative studies will be conducted at various site assessment and/or waste management areas at the Site. This RAWP has been developed to detail the procedures to be used to evaluate human health risks at these areas where risk-based closure may be sought by the Companies, and/or where the evaluation of human health risks is appropriate to support the evaluation of remedial action alternatives.

The HHRA approach outlined here is consistent with basic procedures recommended by the U.S. Environmental Protection Agency (EPA) for conducting risk assessments at waste sites. Documents that will guide the risk assessment include, but are not limited to, the following:

- *Risk Assessment Guidance for Superfund (RAGS), Human Health Evaluation Manual, Part A* (USEPA 1989)
- *Risk Assessment Guidance for Superfund (RAGS), Human Health Evaluation Manual, Part E* (USEPA 2004a)
- *Risk Assessment Guidance for Superfund (RAGS), Human Health Evaluation Manual, Part F* (USEPA 2009a)
- *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA 2002a).

In addition, the risk assessment will follow guidance developed by NDEP applicable to risk assessment, including data evaluation to support risk assessment, provided at the following website: http://ndep.nv.gov/bmi/technical.htm.

The focus of the HHRA will be to evaluate risks associated with conditions that exist or are anticipated to exist at the various site assessment and/or waste management areas following implementation of the remedial decision (i.e., conditions at "closure"). Remedial decisions may inclue an active remedy and/or no further action. For purposes of the NDEP RAS process, these "post-remedy" or "closure" conditions constitute the baseline condition for each site assessment area that will be evaluated in the risk assessment.

The HHRA will address potential exposures and risks assuming that the overall Site will remain an industrial property after closure. As such, the assessment assumes that deed restrictions and institutional controls that limit the use of the Site to industrial activity will be put in place as part of remedial actions. If such restrictions and controls are not implemented the conclusions of the risk assessment cannot be used to predict risks to receptors under alternate future use scenarios.

The HHRA will address potential exposures to onsite industrial/commercial workers, construction workers, maintenance workers, trespassers, and offsite residents. Potential exposures to constituents of potential concern (COPCs) detected in surface and shallow soils will be evaluated for the direct contact pathways, as well as inhalation of vapor-phase and particulate-sorbed contaminants in indoor and outdoor air. For deeper vadose zone soils and groundwater, the potential for vapors to migrate from the subsurface to indoor and outdoor air also will be evaluated.

Direct exposures to groundwater via consumptive use will not be subject to a formal risk assessment. Instead, to support management decisions regarding remedial actions, groundwater quality data will be compared with chemical- and radionuclide-specific standards that define acceptable risk levels for consumptive use. Evaluations related to protection of the overall quality of groundwater as a resource will be evaluated separately as part of the remedial alternatives assessment, but not in the risk assessment.

1.3 ORGANIZATION OF THIS REPORT

The remainder of this document provides a detailed overview of the approaches that will be used to address potential human health risks associated with chemicals that are present in soils or groundwater at the Site. It is organized into the following sections:

- Section 2 – Exposure Scenarios for the Site
- Section 3 – Data Evaluation
- Section 4 – Exposure Assessment
- Section 5 – Toxicity Assessment
- Section 6 – Risk Characterization
- Section 7 – References.

2 EXPOSURE SCENARIOS FOR THE SITE

The exposure scenarios to be considered in the HHRA are dependent upon the exposure pathways relevant to the Site and receptor populations that use the Site. As discussed previously, the exposure scenarios to be evaluated at the Site assume that the site will remain as an industrial facility at closure.

Figure 2-1 summarizes the exposure pathways and receptor populations that will be considered in any HHRA to be conducted at the Site. Importantly, this summary figure is meant to provide a comprehensive listing of the suite of potential exposure pathways and receptors at the Site as a whole. Not all exposure pathways and receptor groups will necessarily be applicable for each site assessment area. The HHRA conducted for each site assessment area will discuss the selection of exposure pathways and receptor groups evaluated and provide the rationale for exclusion of any exposure pathways and receptor groups.

2.1 EXPOSURE PATHWAYS

EPA (1989) has developed the concept of an exposure pathway to define the ways in which receptors might be exposed to constituents. Exposure pathways combine information on the source and transport of a constituent to a point of contact with a receptor and the exposure routes at that point. To be considered complete, an exposure pathway must contain the following elements (USEPA 1989):

1. A source and mechanism of release
2. A retention or transport medium
3. A point of potential contact with the affected medium
4. An exposure route at the contact point.

If any of these elements is missing, exposure will not occur, and the exposure pathway is not complete. Only complete exposure pathways are selected for evaluation in risk assessments.

2.1.1 Sources, Transport, and Contaminated Media (CSM)

A conceptual site model (CSM) is a tool used to describe the source, release, distribution, and transport of chemical constituents to potential receptor populations. As such, a CSM provides detail related to development of exposure pathways for the Site. A draft site-wide CSM has been developed to address contamination associated with the Site. As part of the overall RAS process (NDEP 2008a), this site-wide CSM is being supplemented by the development of area-specific CSMs. These focused CSMs are being used to guide data collection and remedy design

at the various site assessment and/or waste management areas, and also will be useful for determining potentially complete exposure pathways that are relevant at such areas.

The area-specific CSMs will be updated as additional information is collected during site investigation and the evaluation of remedial actions. The draft site-wide CSM (Hargis 2008), however, provides sufficient background information to support a conceptualization of the range of sources, release, fate and transport mechanisms, chemicals, and contaminated media that could be considered in the subject risk assessment.

Briefly, past manufacturing and waste management activities resulted in the release of chemicals to soil and/or groundwater at the former Montrose and Stauffer facilities. These chemicals can be transported in the environment by a variety of mechanisms and reach potential human receptors who contact contaminated media.

In cooperation with NDEP a list of site-related chemicals (SRCs) was agreed upon based on a review of historic Site operations, practices, and analytical data (NDEP 2006a,b). SRCs have been detected in surface soils, subsurface soils, and groundwater at the Site. SRCs for the Site include:

- Volatile organic chemicals (VOCs)
- Semi-volatile organic chemicals (SVOCs)
- Pesticides and related by-products
- Polychlorinated biphenyls (PCBs)
- Dioxins/furans
- Organic acids
- Metals; and
- Asbestos.

In addition to this list, a number of tentatively identified compounds (TICs) have been selected as SRCs for the Site. Hargis (2008) provided a list of SRCs that have been identified for the former Montrose and Stauffer operations. This list is included as Appendix A of this RAWP.

NDEP additionally has requested that radionuclides be addressed in the risk assessment (NDEP 2008b,c), and this RAWP therefore also includes procedures for evaluating radionuclide exposures and associated risks.

For ease of discussion, the previously identified SRCs along with radionuclides are collectively referred to as SRCs in this RAWP. The RAWP provides details on how all SRCs would be evaluated in an HHRA; however, it may be the case that only a subset of this full suite of SRCs will be addressed for a particular site assessment or waste management area. Site-specific conditions that warrant deviation from the list of SRCs presented in this RAWP will be discussed with NDEP prior to generating the HHRA.

SRCs in soil can be directly contacted by persons using the Site. In addition, constituents that are sorbed to soils can be transported to air via wind erosion or due to other physical disturbances of the soil (e.g., vehicle traffic, excavation). Once in air, the soil-sorbed SRCs (i.e., particulates) can be transported to potential receptors both on and off the Site. In addition, vapors that are present in subsurface soils can be transported to the surface and subsequently be dispersed and reach receptors either on- or offsite. Volatile constituents in groundwater also can reach potential receptors as the result of vapor transport through vadose zone soils to surface environments. (As discussed earlier, direct consumptive uses of groundwater will not be evaluated in the risk assessment.) Radioactive elements in soil can additionally release gamma, beta, and alpha radiation to which receptors can be externally exposed.

2.1.2 Exposure Routes

Human receptors can be exposed to SRCs in contaminated media by the following exposure routes:

- Ingestion of contaminated media (e.g., soils)
- Dermal contact (e.g., with soils)
- Inhalation (i.e., vapor or particulate phase constituents).

In addition, human receptors can be exposed externally to certain radionuclides without direct contact or inhalation. These exposures are termed “external exposures”.

2.2 POTENTIAL RECEPTOR POPULATIONS

As discussed earlier, the HHRA will address potential exposures and risks assuming that the overall Site will remain an industrial property after remedial actions have been implemented (i.e., at closure). As such, the primary receptor populations that could be exposed to SRCs at the Site are site workers. Additional onsite exposures could occur for trespassers that illegally enter the Site. Onsite workers and trespassers will be considered in the HHRA. No other onsite receptors will exist.

Some offsite receptors may exist under certain conditions. For example, SRCs that are transported from the Site in air (either as particulate or vapors) also could reach offsite

receptors. The principal offsite receptors are nearby workers and residents. Exposures to offsite workers will be lower than those to onsite workers (due to fewer exposure routes and lower exposure levels); therefore, risks to offsite workers will not be separately evaluated in the risk assessments. Offsite residents, however, constitute a unique receptor population different from onsite workers and so will also be considered for evaluation in the risk assessments.

The principal receptor populations and the routes by which they might be exposed are discussed below. The particular receptors and exposure pathways to be evaluated for any individual site assessment area within the Site will be discussed in the HHRA conducted for that site assessment area.

2.2.1 Indoor Worker

The indoor worker is defined as a long-term, full-time employee who spends most of the day working indoors. Workers may be exposed to outdoor dusts that have infiltrated the building, outdoor soils that have been tracked in, and to contaminants present in indoor air as the result of vapor intrusion.

Potentially complete exposure pathways for the indoor worker are:

- Inhalation of indoor dust
- Inhalation of vapors in indoor air released from soil and groundwater
- Incidental ingestion of surface soil that has been tracked indoors
- External radiation exposure from surface soil that is outdoors, and surface soil that has been tracked indoors (radionuclides only).

Surface soils defined as the top 6 in. of the soil column, are used to define the potential concentrations of SRCs in dust/soils that reach indoors. External radiation exposure to radionuclides that are present in outdoor soil is limited to materials within the top 6 in. of soil; radionuclides found below this level are shielded by the top layer of soil and do not contribute to external radiation exposure (USEPA 2000).

Workers can additionally be exposed to radiation via physical immersion in airborne particulates containing radionuclides. This is a complete exposure pathway (as noted in Figure 2-1) but consistent with EPA guidance for developing preliminary remediation goals (PRGs) for radionuclides (USEPA 2009b), contributes negligibly to overall exposures and will not be evaluated in the risk assessments conducted for the Site.

2.2.2 Outdoor Worker

The outdoor worker is defined as a long-term, full-time employee who spends most of the day working outdoors. This receptor is assumed to participate in relatively low-intensity activities

such as building maintenance, unloading and loading materials and supplies, or occasional digging. Soil exposure for this receptor group is limited to surface soils. Inhalation of vapors as well as dust generated by wind erosion and construction activities also may occur.

Potentially complete exposure pathways for the outdoor worker are:

- Inhalation of outdoor dust
- Inhalation of vapors in ambient air released from soil and groundwater
- Incidental ingestion of surface soil
- External radiation exposure from surface soil (radionuclides only)
- Dermal contact with soil.

Again, external radiation exposure via immersion is also a complete pathway, but contributes negligibly to exposure, and will not be evaluated.

2.2.3 Construction Worker

Construction workers are expected to participate in shorter term, intermittent work at the Site. Work completed by this group might include demolition or construction activities as part of developing infrastructure for future onsite activities. The activities for this receptor may involve substantial onsite exposures to surface and subsurface soils. Workers are assumed to have potential for direct contact with soil from 0-10 ft below ground surface (bgs). Inhalation of dust and vapors also may occur.

The construction workers may contact exposure media via the following exposure pathways:

- Inhalation of outdoor dust
- Inhalation of vapors in ambient air released from soil and groundwater
- Incidental ingestion of surface and subsurface soil
- External radiation exposure from surface and subsurface soil (radionuclides only)
- Dermal contact with surface and subsurface soil.

Given that subsurface soils are hypothesized to be exposed during construction activities, radionuclides in subsurface soil could be a source for external radiation exposures for this receptor group. External radiation exposure via immersion is also a complete, but negligible, exposure pathway for this receptor group.

2.2.4 Trespasser

The trespasser is assumed to have an exposure of intermediate length. For the purposes of this assessment, a trespasser has been assumed to be a teenager (13-19 years old) that illegally enters the Site. Younger trespassers are considered unlikely given the current and anticipated future industrial nature of the Site and surrounding area and the distance of residential areas (i.e., more than one half mile from the Site).

Soil exposure for this receptor group is limited to surface soils. Inhalation of vapors as well as dust generated by wind erosion and construction activities also may occur.

Potentially complete exposure pathways for the trespasser are:

- Inhalation of outdoor dust
- Inhalation of vapors in ambient air released from soil and groundwater
- Incidental ingestion of surface soil
- External radiation exposure from surface soil (radionuclides only)
- Dermal contact with soil.

External radiation exposure via immersion is an additional complete but negligible pathway.

2.2.5 Offsite Resident

Offsite residents could be exposed to SRCs present as vapors or to wind-blown dust released from the Site and dispersed to residential areas. For this scenario, the resident is expected to spend a portion of their time outdoors, and a portion of their time inside the residence.

Offsite residents may contact exposure media via the following exposure pathways:

- Inhalation of dust transported from the Site
- Inhalation of vapors in air released from soil and groundwater at the Site.

Offsite residents also can be exposed to chemicals in outdoor surface soil onto which dust from the Site has been transported, or to indoor dust that has been tracked inside from outside soils. Residential surface soil exposure in the area surrounding the BMI complex is being assessed separately by BRC and will not be included in the risk assessments to be conducted for the former Montrose and Stauffer Site. The risk assessments will include a qualitative discussion of residential risks from exposures to site dust transported to residential surface soils via this exposure pathway. The discussion will be based on risk results for onsite receptors exposed to surface soils, together with information regarding relative soil concentrations (on- and offsite) and exposure characteristics (e.g., duration, frequency).

No radiation exposures to residents will be evaluated in the risk assessments. External radiation exposure to offsite residents from soil that remains at the Site or radon gas that can be transported from the Site are potentially complete exposure pathways. Given the distance from the Site to the nearest residence, however, the amount of radiation that will reach offsite residents via these pathways will be negligible compared to external radiation exposures experienced by site workers, and will not be evaluated in the risk assessment. Similarly, external radiation exposure via immersion in outdoor dust is a potentially complete but negligible exposure pathway and will not be evaluated.

3 DATA EVALUATION

Analytical data collected as part of past and future site investigations will be the source of the SRC data evaluated in the risk assessments. This section describes the types of data that may be used for the risk assessments as well as the proposed procedures to 1) evaluate and select data for use in each risk assessment, 2) process analytical sample results to support use in each risk assessment, and 3) select specific SRCs for quantitative evaluation in each risk assessment.

3.1 DATA TYPES

The following types of data will be evaluated in the risk assessments, as available:

- Soil data – all SRCs
- Groundwater data – volatile SRCs
- Soil vapor data - volatile SRCs
- Flux chamber data - volatile SRCs.

Groundwater and soil data will be used to define source characteristics in the case that vapor transport is modeled. The groundwater data that will be used in such a modeling exercise will be that collected from the alluvial aquifer (i.e. Shallow Zone) and fine-grained Upper Muddy Creek Formation. This groundwater is closest to the surface and therefore best represents the potential source of groundwater chemicals available for vapor transport to the surface, which is the only groundwater-related pathway with a potentially completed exposure pathway. As mentioned earlier, direct consumptive use of groundwater will not be evaluated in the risk assessment. The quality of all groundwater (shallow and deep) will however be evaluated separately as part of the remedial alternatives assessment.

For modeling purposes, volatile SRCs will be defined as those categorized as such by EPA's *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway From Groundwater and Soils (Subsurface Vapor Intrusion Guidance)* (2002b). SRCs identified as volatile by EPA are listed in Appendix B. If EPA (2002b) has not reviewed a particular SRC for volatility (2002b), NDEP's determination of chemical volatility that is presented in its table of basic comparison levels (BCLs) (NDEP 2009a) will be used. If measured soil vapor concentrations (e.g., from soil vapor probes or soil vapor flux chamber sampling) are used to assess vapor exposures, all detected chemicals will be evaluated.

3.2 DATA REVIEW AND SELECTION

Available analytical data will be reviewed to determine its suitability for use in each risk assessment. NDEP procedures outlined in guidance issued for assessing data usability for

environmental investigations at the BMI Complex and Common Areas (NDEP 2008d) will guide the assessments. Data usability evaluations will be completed prior to the risk assessments, and will be documented in reports following specifications outlined by NDEP (2008d). The risk assessments may include a summary of data that are excluded from the risk assessment based on the data usability evaluation, if the exclusion is believed to have introduced significant uncertainty into the risk assessment. Findings will be discussed in the uncertainty section of the risk assessment conducted for each site assessment or waste management area.

3.3 DATA PROCESSING

Following the data usability evaluation, data deemed of sufficient quality to support the risk assessment will be compiled in a database to support the exposure and risk calculations. The universe of relevant sampling data for the Site may include detected and non-detected values, duplicate samples, and split samples. The treatment of these different data types will follow EPA (USEPA 1989, 1992a,b) and NDEP guidance (2008d,e,f) and is discussed below.

3.3.1 Detected Analytes

Laboratory results can be broadly classified as detects or non-detects. Detected results reflect cases in which a measurable quantity of a constituent was determined and reported by the laboratory. Detected results may have a qualifier assigned by the laboratory, or during data validation process. As part of the data usability evaluation, all qualifiers assigned to detected data will be reviewed and treated in accordance with EPA guidance (USEPA 1989, 1992a,b). Detected data that are deemed appropriate for use in the risk assessment by the data usability evaluation will be used at the full reported value.

3.3.2 Non-Detects

Cases where analytical parameters are not detected above some measurement threshold are defined as non-detections. Non-detected results are qualified as such by the laboratory and an associated quantitation limit is provided. Non-detected values can also carry other qualifiers assigned during the analysis or validation process. As part of the data usability evaluation, the qualifiers assigned to all non-detected values will be reviewed using EPA guidance (USEPA 1989, 1992a,b). All non-detected results that are considered appropriate for use in the risk assessment will be included in the database.

For non-detected results the sample quantitation limit (SQL)[2] will be reported for all analytes with the exceptions of radionuclides and asbestos. For radionuclides the minimum detectable activity (MDA)[3] will be reported. For asbestos, the reported analytical sensitivity for the non-detected sample will be presented.

Summary statistics characterizing both detected concentrations, and the quantitation limits specified above for non-detected results, will be provided in a form consistent with NDEP guidance (NDEP 2008e).

3.3.3 Duplicate and Split Samples

Duplicate samples and split samples are commonly included as part of data collection efforts for assessing environmental contamination. A field duplicate is a distinct sample collected from the same point in time and space as the first sample, or as near to the same time and place as possible. A field split sample is derived from a sample homogenized in the field; the homogenized sample is split into two samples, each of which is analyzed separately. The second sample is assigned the label of field split and is considered the quality control (QC) sample (NDEP 2008f).

Following NDEP recommendations (NDEP 2008f) the treatment of duplicate and split samples will depend on the variance of the QC sample and the site sample results. Sample results will be summarized to determine whether the variance between QC samples and site samples is similar. If appropriate to the data (e.g., sufficient sample size), statistical tests will be used to evaluate if variance in the QC samples is similar or different from the site samples. Following the assessment of variance, duplicate and split samples will be treated for use in the risk assessment as follows:

Duplicates with variance similar to site samples –

- Samples will be treated independently. All results will be carried forward in the quantitative characterization of Site SRCs.

All splits, and duplicates with a variance that differs from site samples –

- The result of the first sample will be carried forth in the quantitative characterization of Site SRCs. The second QC sample will not be carried forward in a quantitative manner.

[2] SQLs are sample-specific detection limits. They are usually an adjustment from the method detection limit (MDL) and reflect sample-specific actions, such as dilution or use of smaller aliquot sizes, and take into account sample characteristics, sample preparation, and analytical adjustments.
[3] The MDA is the lowest level of activity in a given sample that is statistically distinguishable from a sample with no activity, at the 2-sigma confidence interval. MDAs for radionuclide analysis take into account sample volume, chemical recovery, instrument detection efficiency and background, and sample counting duration.

Uncertainties associated with the choice of the first sample will be tracked in the risk assessment and discussed in the uncertainty section as relevant.

3.4 SELECTION OF COPCS FOR EVALUATION IN THE RISK ASSESSMENT

More than 300 chemicals and analytical parameters have been identified as SRCs for the Site. To focus the risk assessment on those SRCs that are most important to defining potential human health risks at any given site assessment area, a series of screening steps will be applied to the data to select the particular SRCs to be considered in the risk evaluation. The SRCs selected for evaluation in the risk assessments are termed COPCs.

For purposes of the risk assessments, all analytes have been grouped initially by chemical class. The SRC group classifications presented in Hargis (2008), and presented in Appendix A, will be used to characterize Site SRCs with the addition of radionuclides.

The following SRCs/SRC Groups will not be selected as COPCs for the risk assessments.

- **General and indicator chemicals**. This group of general analytical parameters (e.g., alkalinity, chloride, pH, sodium, sulfate) were used at the Site primarily to characterize general site conditions (e.g., total inorganic and total organic carbon) or as indicators of the potential presence of other SRCs (e.g., pH as an indicator for acid SRCs, ions for several of the salts). The potential toxicity and risks from this group of SRCs will not be evaluated. Some of these parameters (e.g., total organic carbon, alkalinity) are not considered potential toxicants, and others in this group, though potentially toxic in certain situations (e.g., high sodium), are best evaluated by focusing on the particular SRC the indicator chemicals were used to identify.

- **Inorganics**. This SRC group as defined in Hargis (2008) is comprised of fluoride, iodide, nitrate, and total carbon, and has been used at the Site primarily to understand general chemical conditions. These SRCs will be used to understand conditions at the Site but will not be separately evaluated for toxicity or risk, for the same reasons noted for general and indicator chemical groups.

- **Total petroleum hydrocarbons (TPH)**. This is another type of a general indicator SRC group (in this case, for petroleum products). Because toxicity is dependent upon the individual constituents that comprise the TPH mixture, the potential toxicity or risks associated with TPH exposure will be evaluated for the constituent SRCs as reported in the database. The potential toxicity and risks from TPH as a whole will not be evaluated separately.

- **Tentatively Identified Compounds (TICs)**. TICs will not be selected as COPCs for quantitative evaluation in the risk assessment because of the uncertainty associated with the identity of these compounds. These data will be evaluated qualitatively; however, and the potential risk implications discussed in the risk assessment.

The remaining SRCs will be further evaluated for selection as COPCs for inclusion in the risk assessments. The primary criteria to be used to select COPCs are a comparison to naturally occurring (background) levels and a comparison to risk-based levels. These steps are discussed in more detail below. For some site assessment areas, a frequency of detection screen may additionally be used to select COPCs, if SRCs are detected infrequently in any given area. This screen would not be used in any site assessment area without prior approval by NDEP, however.

3.4.1 Background Comparison

NDEP and EPA guidance allows for the elimination of constituents from further evaluation if detected levels are not elevated above naturally occurring levels (NDEP 2009b; USEPA 1989). Because metals and radionuclides occur naturally in the environment, concentrations of these constituents will be compared to background concentrations. Metals and radionuclides that are present at the Site at concentrations that are similar to regional background concentrations will not be selected as COPCs.

The background dataset to be used for the background/onsite comparisons will be selected as part of the data usability evaluation. This selection will consider representativeness, comparability to onsite data, and statistical power/sample size of available background datasets. The selection and justification of the background data to be used for onsite comparisons will be included in the data usability evaluations and in the risk assessment reports.

As recommended by NDEP in past communications with the Companies, comparison of onsite and background data will be conducted via hypothesis testing using EnviroGiSdT Software developed by Neptune and Associates. As outlined in the software's users' manual (Neptune and Company, Inc. 2008), four two-sample hypothesis tests are conducted as part of background comparisons: the t-test, the Wilcoxon Rank Sum test using the Gehan ranking scheme, the Quantile test, and the Slippage test. Because considering the results of four tests in combination increases the overall false rejection rate for the entire procedure, an adjusted significance level aimed at producing an overall false rejection rate of 0.05 will be adopted for each test. Results from statistical tests, consideration of their robustness and limitations, and graphical displays of the data will be used to determine whether onsite concentrations of metals and radionuclides exceed background concentrations.

In addition to direct comparisons with background data as described above, radionuclide data will additionally be evaluated by analysis of secular equilibrium (SE), following guidance prepared by NDEP (2009b). The presence or absence of SE for onsite data can be used to characterize the source of radionuclides. SE exists when the quantity of a radioactive isotope remains constant because its production rate is equal to its decay rate; under natural background conditions approximate SE is expected. In the case that onsite radionuclide data do not exhibit SE there is an indication of radionuclide-specific contamination (NDEP 2009c).

Natural chemical and physical processes may cause some deviations from SE, and only approximate or quasi-SE can be expected even under the best field, and ideal testing conditions. In order to accommodate small differences, equivalence testing, which allows some flexibility in terms of the statistical hypothesis tested, will be employed. The equivalence testing approach will follow the protocols set forth by NDEP's (2009c). Standard background comparisons, described above, and the analysis of SE will be considered together in determining whether onsite radionuclides differ from background.

3.4.2 Risk-Based Screening

Soil SRCs that remain after the above screening step will be further screened by comparing to risk-based concentrations. No risk-based screening will be conducted for groundwater, soil vapor, or flux box data. Instead, all volatile SRCs (as determined using screening described in Section 3.1) will be evaluated if detected.

The risk-based concentrations to be used in the screening for SRCs in soil are BCLs developed by NDEP for chemicals (NDEP 2009a), and PRGs for radionuclides developed by EPA (USEPA 2009b). (NDEP has not developed BCLs for radionuclides.) BCLs and PRGs are based on direct contact exposure pathways (ingestion, inhalation, and dermal absorption). For radionuclides the external radiation pathway is also considered in their derivation. The BCLs and PRGs correspond to a target excess cancer risk of one in one million ($1x10^{-6}$), or a noncancer hazard quotient (HQ) of 1. BCLs and PRGs[4] developed for commercial/industrial settings will be used.

Soil SRCs that remain after the comparison to background levels will be evaluated by comparing the maximum detected concentration to one-tenth the value of the BCL or PRG for industrial/commercial soils (NDEP 2009a). Per NDEP guidance, the exceptions to this are lead, which will be compared directly to the commercial/industrial BCL of 800 mg/kg (NDEP 2008g), and titanium, which might be compared to a concentration limit that is lower than one-tenth of the BCL if it is present in substantial amounts in a form other than titanium metal or titanium oxide (NDEP 2008h).

[4] PRGs for radionuclides are based exclusively on carcinogenic health effects.

Any organic SRC passing the initial screening steps that has a maximum detected concentration that exceeds the risk-based screening evaluation discussed above will be selected as a COPC for risk assessment. Similarly, any metal SRC or radionuclide that exceeds the risk-based screening and exceeds regional background levels and/or shows deviations from SE, will be selected as a COPC.

Risk based screening will not be completed for asbestos in soil. The detection of amphibole or chrysotile fibers will be used to screen asbestos for the quantitative risk evaluation.

4 EXPOSURE ASSESSMENT

The magnitude of exposure for any given receptor is a function of the amount of the constituent in the exposure medium and the frequency, intensity, and duration of contact with that medium. This section presents an overview of the equations and assumptions that will be used to calculate potential exposures as part of the risk assessments to be conducted at the Site.

4.1 GENERAL APPROACHES TO EXPOSURE CALCULATIONS

For chemical (non-radiological) constituents, oral and dermal exposures are expressed in terms of intake (i.e., mg chemical per kg body weight per day – mg/kg-day), whereas inhalation exposure is expressed in terms of an exposure concentration (EC) in air (e.g., $\mu g/m^3$). These different expressions of exposure are used to match the toxicity criteria that are available to calculate risks for each type of exposure. For radionuclides, exposure is expressed as total dose in terms of pico Curries (pCi).

The general approaches for quantifying exposures for chemicals and radionuclides are discussed below. The approaches for quantifying exposures to asbestos are unique and discussed separately later in this section.

4.1.1 Chemical Exposures

Chemical exposures for each scenario will be calculated using site-specific chemical concentrations and receptor- and scenario-specific exposure assumptions.

The following equation is a general form of the equation used to estimate intake for oral and dermal exposures:

$$Intake\ (mg/kg \cdot day) = \frac{CR \times C \times CF \times EF \times ED}{BW \times AT} \qquad \text{Eq. 4-1}$$

where,

CR = contact rate (e.g., mg/day)

C = contaminant exposure point concentration (e.g., mg/kg)

CF = conversion factor (e.g., 10^{-6} kg/mg)

EF = exposure frequency (days/year)

ED = exposure duration (years)

BW = body weight (kg)

AT[5] = averaging time (days).

Intake will be expressed in various forms, depending on the risks that it will be used to assess. Average daily dose (ADD) and lifetime average daily dose (LADD) will be calculated and used as measures of exposure from oral and dermal routes, for characterizing noncarcinogenic and carcinogenic effects, respectively.

The EC is a function of a chemical's concentration in air measured at the exposure point and scenario-specific parameters, such as exposure duration and frequency. The following equation is a general form of the equation used to estimate the EC:

$$EC\ (\mu g/m^3) = \frac{C_{air} \times ET \times EF \times ED}{AT} \qquad \text{Eq. 4-2}$$

where,

C_{air} = contaminant concentration in air (μg/m^3)

ET = exposure time (hours/day)

EF = exposure frequency (days/year)

ED = exposure duration (years)

AT[5] = averaging time (hours).

4.1.2 Radionuclide Exposure

Unlike chemicals, radionuclide exposure is typically expressed in units of activity per unit of the exposure medium, rather than mass per unit. Exposure to radionuclides may result from internal and external exposure pathways.

Internal exposure is expressed for completed pathways using the following equation:

$$Dose\ (pCi) = C \times CR \times EF \times ED \qquad \text{Eq. 4-3}$$

[5] When evaluating cancer risk, the averaging time (AT) is equal to a lifetime of 70 years. When evaluating noncancer hazard, the AT is equal to the total exposure duration.

where Dose is the dose due to internal exposure, and the remainder of the variables are the same as Equation 4-1 above, except that "C" is the concentration term for soil or air expressed in units of pCi/g, or pCi/m^3, respectively, and "CR" is the contact rate expressed in the relevant units (i.e., g/day, m^3/day) for that medium. The body mass and averaging time (AT) exposure factors are not relevant for radionuclides.

For some radionuclides, exposure via certain internal pathways (e.g., oral, dermal, or inhalation) may be insignificant (USEPA 2000). For instance, as reflected by their small dermal absorption and dermal permeability constants, dermal absorption of radionuclides is not an important pathway (USEPA 2000). The inhalation of particulates from dust represents significant exposure for only a few radionuclides (USEPA 2000). Quantitative exposure assessments will only be completed for significant pathways. The selection of pathways for quantitative evaluation will depend upon the radionuclide constituents that are present in and near each site assessment area and will be discussed in the individual risk assessment reports.

The external dose for radionuclide exposure will be calculated using the following equation:

$$Dose\ (pCi\text{ - }yr/g) = C_{soil} \times \left[EF/CF_{DY}\right] \times ED \times ACF \times \left[ET_O + \left(ET_i \times GSF\right)\right] \qquad \text{Eq. 4-4}$$

where,

C_{soil}	=	exposure concentration term for soil (pCi/g)
EF	=	exposure frequency (days/year)
CF_{DY}	=	conversion factor (days/year)
ED	=	exposure duration (years)
ACF	=	area correction factor (unitless)
ET_o	=	fraction of time spent outdoors (unitless)
ET_i	=	fraction of time spent indoors (unitless)
GSF	=	gamma shielding factor (unitless).

The exposure frequency (EF) and exposure duration (ED) are the same as described above for calculating internal exposures to non-radiological and radiological constituents. As described in the context of internal exposures to radioactive constituents above, "C" is the concentration term for soil expressed in units of pCi/g.

The EPA model for external radiation assumes that an individual is continually exposed to a non-depleting radiological source that is effectively an infinite slab. The concept of an infinite

slab means that the thickness of the contaminated zone and its aerial extent are so large that it behaves as if it were infinite in its physical dimensions. Source areas contaminated to a depth greater than 15 cm with an aerial extent greater than 1,000 m^2 will create a radiation field comparable to an infinite slab (USEPA 2000). The area correction factor (ACF) adjusts for smaller source areas. EPA has derived ACFs for various source area sizes, ranging from 10-10,000 m^2 (USEPA 2009b). These will be used to assess radiological risks at various site assessment areas at the Site.

The gamma shielding factor (GSF) is a factor that accounts for the shielding effect provided by buildings during times of indoor occupancy or other site features. The fraction of time spent exposed in outdoor and indoor environments is described by ET_O and ET_i, respectively.

4.1.3 Range of Exposure Assumptions

The variables/exposure factors shown in the exposure algorithms above vary depending on the receptor population being evaluated. Each receptor population will be characterized by a number of assumptions regarding the frequency of contact with potentially contaminated media, duration of exposure, and other parameters unique to the receptor population.

EPA (1992c) guidance for Superfund sites recommends that two types of exposure estimates be calculated. The reasonable maximum exposure (RME) is defined as the highest exposure that could reasonably be expected to occur for a given exposure pathway at a site. The RME is intended to account for both uncertainty of the contaminant concentration and variability in exposure parameters. EPA also recommends that an average estimate of exposure, termed "central tendency exposure" (CTE), be presented in the risk assessment. Both RME and CTE estimates will be calculated for the risk assessments[6].

The specific equation and assumptions used to estimate exposure varies, depending on the exposure route being evaluated. Appendix C presents a complete set of exposure equations along with the specific exposure assumptions that will be used for contact rate, EF and exposure ED, body weight (BW), and AT for each pathway and receptor group. It additionally presents exposure factors specific to radionuclide exposures including ET_O, ET_i, and GSF.

General assumptions that are applicable to exposure estimates are discussed in Section 4.1 below. In addition to exposure assumptions, COPC concentration in the exposure medium at the point of contact are required for evaluating risks. Section 4.2 describes the approaches used to estimate exposure point concentrations (EPC).

[6] In the case that lead is brought forth as a COPC in the risk assessment, only CTE estimates will be calculated. The adult lead methodolgy (ALM) is sensitive to upper end values, and specifies the use of central tendency soil lead concentrations (USEPA 2003a).

4.2 GENERAL INTAKE ASSUMPTIONS

Exposure assumptions for ED, EF, BW, and AT are discussed below. EPA guidance was used as the basis of these values, if available.

4.2.1 Exposure Duration

The ED is the length of time during which someone may be exposed to a particular medium via a specific exposure pathway. The ED varies depending on the population being evaluated. Both chronic and subchonic exposures will be assessed at the Site, depending upon the receptors evaluated. EPA (2009a) defines chronic exposures as repeated exposures that occur over 7 years[7] or more, and subchronic exposures as repeated exposures that occur over a period greater than a month and less than 7 years.

For a typical indoor or outdoor occupational worker, chronic exposures are evaluated. EPA (2002a) recommends an RME ED of 25 years. This value is based on U.S. Census data and represents an upper bound estimate for the length of time a person works at the same location. The average, or CTE, value for occupational ED is assumed to be 7 years, which is the median occupational tenure of the working population (USEPA 1997a).

Construction workers are expected to work on limited-term projects, such as building construction, and are assessed for subchronic exposures. If multiple construction projects occur on the site, it is assumed that different workers will participate in each project. EPA recommends an ED of 1 year for construction workers (USEPA 2002a). For this risk assessment, based on best professional judgment, a value of 6 months is proposed as the CTE value.

Trespassers also will be evaluated for subchronic exposures. The trespasser scenario to be used for the Site assumes that a teenager from the surrounding community accesses the Site without permission. EPA guidance on the duration of exposure for trespassers is not available. Given the assumption that exposure does not begin before the age of 13, a RME and CTE ED of 6 years, and 3 years respectively, are proposed for this scenario at the Site, based on best professional judgment.

RME and CTE EDs for the resident are 30 years and 9 years, respectively. These values represent the 95th and 50th percentile values for years lived in the same house (USEPA 1997a). It is assumed that 6 and 2 years of the 30 and 9 year periods respectively, occur as a child. The decision to assume 2 years of the 9 year CTE ED as the portion occurring during childhood is based on best professional judgment; the value is approximately equal to the ratio of 24 adult years to 6 child years, recommended by EPA and applied for the RME scenario.

[7] Seven years is one-tenth of an EPA-assumed standard lifetime of 70 years.

4.2.2 Exposure Frequency

EF describes how many days someone may have contact with the exposure media of interest in a typical 1-year period.

EPA recommends an RME EF of 250 days/year for indoor workers and 225 days/year for outdoor workers (USEPA 2002a). These values will be adopted for the RME and CTE cases for these receptor groups. EPA recommends an EF of 250 days/year for construction workers (USEPA 2002a). This value will be used as an RME and CTE value.

Guidance is not available for the number of days that trespassers could be assumed to enter a site. Considering the sparse rainfall that occurs in the area, it is possible that the trespasser might access the site throughout the year. Based on best professional judgment it is conservatively assumed that the trespasser accesses the site an average of 2 days/week throughout the year, and an ED of 100 days/year is recommended for the RME value. For the CTE value, it is assumed that the trespasser enters the site an average of one day/week throughout the year, or 50 days/year.

An EF of 350 days/year is assumed for residents, as recommended by EPA (1991).

4.2.3 Body Weight

A value of 70 kg (154 lbs) represents the BW for all adults, based on average male and female adult BWs (USEPA 1991). This value will be used for all RME and CTE worker scenarios and adult residents. A BW of 15 kg is assumed for the child resident (USEPA 1991). These values will be used for CTE and RME scenarios. The trespasser is assumed to be an individual between 13 and 19 years of age. A value of 60 kg (132 lbs), based on average male and female BW for this age category, will be used for CTE and RME scenarios (USEPA 1991). This parameter is not included in dose estimation for radionuclides (USEPA 1989).

4.2.4 Averaging Time

The AT is the period over which an exposure is averaged. The ATs for evaluating carcinogenic and noncarcinogenic effects are different, and are expressed in different units dependent on the exposure route being evaluated. For evaluating carcinogenic effects, chemical intakes are averaged over a 70-year lifetime (25,550 days; 613,200 hours) to be consistent with the method by which cancer slope factors (CSF) are derived (USEPA 1989). When evaluating noncarcinogenic effects, chemical intakes are averaged over the ED (USEPA 1989).

Therefore, for noncarcinogenic effects, the ED is converted to days or hours and is used as the AT_{nc}. For example, the RME AT for the outdoor occupational and indoor worker is 25 years, or 9,125 days, or 219,000 hours; the RME for trespassers is 6 years, or 2,190 days, or 52,560 hours;

and the RME AT for the nearby residents (adult and child component) is 30 years, or 10,950 days, or 262,800 hours.

This parameter is not included in dose estimation for radionuclides (USEPA 1989).

4.3 EXPOSURE POINT CONCENTRATIONS

EPCs will be estimated using measured concentrations of chemicals and radionuclides in environmental media alone or in combination with fate and transport models. Both RME and CTE EPCs will be derived. Methods for deriving EPCs in soil, airborne particulates, and ambient and indoor air vapors are described below.

4.3.1 Exposure Point Concentrations in Soil

Soil EPCs will be calculated to estimate direct contact exposure for onsite workers. The soil EPCs could also be used as inputs to emission models used for deriving airborne concentrations of SRCs released into the atmosphere as particles or vapors.

EPCs from soil will be derived using data results from soil samples taken within site assessment or waste management areas. Representative EPCs will be based on the potential exposure depth interval for each receptor. For receptors exposed to surface soil (e.g., for indoor workers, outdoor workers, trespassers), data from the top 6 in. of soil will be used. For receptors exposed to deeper soils (e.g., construction workers) data from the surface to 10 ft bgs will be used.

To estimate exposures that are representative of upper end exposures, EPA (1992c) recommends using the 95th upper confidence limit (UCL) of the arithmetic mean concentration. As recommended in past communications with NDEP, 95th UCLs will be estimated using EnviroGiSdT Software. EnviroGiSdT provides three methods for computing the UCL; the Student's t- UCL and 2 bootstrap UCL methods. For each COPC the sample size, frequency of detection, and data distribution will be evaluated in order to select the appropriate method for computing a UCL. Currently, the EnviroGiSdT Software uses one-half the SQL/MDA for non-detected results when computing the 95th UCL. If the substitution of one-half of the SQL/MDA for non-detects appears to be driving the risks, alternative substitution methods for non-detects may be explored within the uncertainty evaluation.

In the cases that lead is brought forth as a COPC in the risk assessment, the arithmetic mean concentration of lead in soil will be adopted as the EPC for estimating risk. The Adult Lead Methodolgy (ALM), which will be used to characterize risks from exposure to lead, is sensitive to upper end values, and specifies the use of central tendency soil lead concentrations (USEPA 2003a).

Results of statistical analyses conducted to determine the distribution of the data and the recommended UCL will be provided in the risk assessment.

4.3.2 Airborne Particulates

Airborne particulate concentrations will be calculated for dust emissions sources within a given site assessment area. For the purpose of this RAWP, airborne particulates will include nonvolatile chemicals, radionuclides, and asbestos. The emissions and dispersion modeling described in this section will be applied to all airborne particulates evaluated in the risk assessments. However, there are unique analytical data handling procedures used to develop the asbestos concentration to be used in the emissions models. These unique asbestos procedures are detailed at the end of this section on airborne particulates.

4.3.2.1 Emissions and Dispersion Modeling for Chemicals and Radionuclides

There are two primary sources of dust emissions for site assessment areas at the Site: wind erosion, and soil disturbances associated with construction activities. For most SRCs, the incidental ingestion and dermal absorption exposure pathways to be quantified in the site risk assessment will result in higher potential health risks than the inhalation pathways. Therefore a tiered modeling approach that progresses from a simplified and upper-bound assessment to a refined and more accurate estimate of potential health risks is proposed for evaluating inhalation exposures related to airborne particulates released from the site assessment area being addressed. If the inhalation pathway risks based on the simple site-specific method drive the overall risks to the site assessment area, then more refined and less conservative tiers will be used.

The airborne particulate concentrations will be calculated separately for dust emissions from wind erosion and from construction-related activities for all modeling tiers. Dust emissions from construction activities are assumed to occur for a limited period (i.e., no more than 1 year) whereas emissions from wind erosion can occur throughout the assumed exposure period for any receptor. For construction workers, the airborne particulate concentrations for the risk assessment will be based solely on the emissions from construction related activities because the relative contribution from wind erosion would be insignificant. For all other receptors, a time-weighted airborne particulate concentration will be calculated to reflect the combined emissions from short-term construction activities and long-term wind erosion.

The first tier for estimating airborne particulate concentrations will be based on the simplified site-specific methods provided in EPA's Soil Screening Guidance (USEPA 2002a). EPA (2002a) has identified vehicle traffic as the most significant contributor to fugitive dust emissions during construction activities. Dust emissions for construction activities will be based on assumed vehicle traffic over unpaved surface soil. A particulate emission factor (PEF) equation is provided by EPA (2002a) for estimating the chemical concentration in air associated with the

surface soil concentration of the source. Separate PEF equations are provided by EPA (2002a) for construction workers and offsite residents. The PEF for construction workers assumes that exposure occurs within the area where soil disturbances are occurring.

The site-specific value for construction time will be matched to the exposure duration (i.e., 6 months for CTE and 1 year for RME). The development area to be modeled in the risk assessment will be dependent on the size and characteristics of the site assessment area being addressed. The general default assumption for the hypothetical construction scenario will be assumed as 5 acres for the CTE case, and 10 acres for the RME case. The soil concentrations for COPCs will be based on the 95th UCL for the site assessment area soil for 0-10 ft bgs. A sensitivity analysis will be conducted for the model inputs to evaluate their impact on uncertainties in the risk estimates. This analysis will include consideration of localized areas of elevated soil concentrations relative to the 95th UCL for the entire site assessment area. For example, if the lateral dimensions of the site assessment area are larger than the default development area sizes, then the data may be subdivided in to smaller groups to calculate 95th UCL values that more accurately represent each unique development area. Appendix D provides a summary of the values to be used for PEF model parameters shown above.

An integral part of the PEF equation is the dispersion factor which provides an estimate of the dilution that occurs during transport from the emission source to the point of exposure once dust is released into the atmosphere. The dispersion factor is linked to the PEF to calculate the airborne particulate concentration. EPA (2002a) provides a dispersion factor for the construction worker exposure that is based on air concentrations predicted at the edge of a straight road bisecting a square area assumed to represent the source. A series of square source areas from 0.5 to 500 acres were modeled using a unit flux rate and a range of typical meteorological conditions. The only site-specific parameter in the dispersion factor equation is the source size. Given the PEF for the construction scenario is based on the area of development, the actual source size determined for the site assessment area, or the default source area value of 5 acres for the CTE case and 10 acres for the RME case, will be used to estimate the dispersion factor. For offsite residents and outdoor workers, the PEF accounts for contributions from both construction and wind erosion. However, the fugitive dust emissions from construction activities are very brief relative to the emissions from wind erosion. Therefore, the PEF for offsite residents and onsite workers is designed to normalize the mass of fugitive dust released over the exposure duration for a given receptor. This normalization process provides a means to account for the significant differences in the amount of time during which each fugitive dust source operates. In the simplified site-specific approach provided by EPA (2002a) vehicle traffic on unpaved roads is used to estimate the fugitive dust emissions from construction activities.

Appendix D provides details of the PEF model equations and the input parameters that will be used in the risk assessments. The parameter values assumed for the outdoor worker and offsite resident are consistent with those assumed for the construction worker. The soil concentrations for COPCs will be based on the 95th UCL for the Site for 0-10 ft bgs. A sensitivity analysis will

be conducted for the model inputs to evaluate their impact on uncertainty in the risk estimates. This analysis will include consideration of localized areas of elevated soil concentrations relative to the EPC based on all data within the site assessment area. As discussed earlier, a particular site assessment area could be large enough to support several unique development areas, in which case it may be appropriate to subdivide the soil data and calculate a 95th UCL that reflects the individual development areas.

For the wind erosion component of the fugitive dust emissions the aerial extent used in the PEF will be based on the size of the site assessment area rather than the area of development as used in the construction PEF. This assumption ignores the fact that some areas of the site assessment area may be impervious to wind erosion. The fraction of vegetative cover will be set at zero in the first tier analysis, which optimizes the potential for wind erosion emissions from the Site. The soil concentrations for COPCs will be based on the 95th UCL for soils 0-6 in. bgs. A sensitivity analysis will be conducted for the model inputs to evaluate their impact on uncertainty in the risk estimates. This analysis will include consideration of localized areas of elevated soil concentrations relative to the site assessment area wide EPC used to evaluate the COPCs. If construction activities are assumed to occur within a site assessment area, the area wide 95% UCL for soils 0-6 in. bgs will be compared to the 95% UCL for soils 0-10 ft bgs in the development areas. The comparison will determine the need to consider alternative approaches to using only the 0-6 in. bgs soil for evaluating wind erosion (e.g., area-weighted values or separate wind erosion area sources). A complete listing of the PEF equations and input values is presented in Appendix D.

The EPA (2002a) dispersion factor used in the wind erosion PEF equation assumes that the receptor is located either at the edge, or in the center, of the emission source, Outdoor workers are assumed to be exposed at the center, and residents are located at the downwind edge, of the wind erosion source area. The EPA (2002a) dispersion factor is based on air modeling using a unit flux rate and square area sources ranging from 0.5 to 500 acres. Maximum annual-average concentrations were derived using meteorological data from 29 sites throughout the United States. EPA (2002a) provides the necessary information to modify the dispersion factor to reflect the area source size and the climatic region where the exposure occurs. The dispersion factor will be modified using the climate-related inputs provided by EPA for Las Vegas, NV. Despite these adjustments to the dispersion factor, the calculation will still provide an upper-bound estimate of the exposure point air concentration for residents due to the fact that they are conservatively assumed to spend their entire exposure period located at the edge of the fugitive dust emission sources.
If the simplified site-specific approach to fugitive dust emissions dominates the overall risk estimates for a specific receptor, the EPCs will be recalculated using a more refined approach. The next level of refinement would be to conduct the detailed site-specific calculations of fugitive dust emissions as recommended by EPA (2002a). The basis for this more detailed site-specific approach for dust emissions would be the algorithms provided for such analysis in Appendix F of the EPA *Supplemental Soil Screening Guidance* (2002a).

The detailed site-specific approach allows for the application of considerably more site-specific variables in the emissions estimation, which should reduce the amount of over-estimation in the associated risks. If application of the detailed site-specific approach recommended by EPA yields inhalation risks that dominate the total site risks for a receptor, a refined site-specific air modeling using an EPA approved model will be proposed. Use of a site-specific refined air model would allow us to place receptors at the appropriate distances and directions from assumed dust emissions sources and use site-specific meteorological data to derive more accurate estimates of airborne particulate concentrations. The fugitive dust emission estimates developed from the detailed site-specific approach would be linked with the air model to develop the more refined estimate of the airborne particulate concentration.

4.3.2.2 Asbestos Airborne Exposure Point Concentrations

Asbestos concentrations in site soils have been characterized using an elutriator method that reports the number of asbestos structures detected per mass of respirable dust (Berman and Kolk 2000). The intent of this method is to provide analytical asbestos measurements that can be directly combined with standard dust emission and dispersion models to predict airborne asbestos concentrations associated with soil disturbances that would release respirable dust. This asbestos measurement methodology was employed as part of an NDEP-approved sampling and analysis plan for site soils (PES 2006). This methodology has also been employed for NDEP approved risk assessment activities at adjacent sites (ERM 2007).

Recently the EPA (2008a) has issued guidance for investigating asbestos contaminated Superfund sites. This new EPA guidance recommends that activity based sampling be conducted if it is determined that humans could be exposed to airborne asbestos released from a site under current or future site conditions. Activity based sampling requires disturbing the soil containing the asbestos in a manner that simulates expected activities at the site and measuring the airborne concentrations that result. The airborne concentrations can then be used with recommended exposure factors and toxicity criteria to determine the potential risk to humans. Adopting this new EPA guidance for use at the Site would be a significant departure from the method currently supported by NDEP. Therefore, no attempt will be made in this RAWP to anticipate what might be required by NDEP if they choose to adopt this new EPA asbestos guidance. Rather, the specifics of an activity based sampling program for asbestos, if required by NDEP, would be developed in consultation with NDEP under separate cover or as an amendment to this RAWP. The remaining discussion of asbestos emissions and dispersion modeling will describe the approach for handling data obtained from the NDEP approved elutriator method.

The asbestos sampling results from the elutriator method is reported as structures per gram of respirable dust. The emissions and dispersion modeling discussed in Section 4.3.2.1 describes the approach for estimating the respirable dust concentration in air resulting from the various soils disturbing activities anticipated at the Site. The product of the airborne respirable dust

concentration and the asbestos elutriator results yields an estimate of the airborne asbestos concentration that can be used in calculating potential human health risks as described in Sections 5 and 6 of this RAWP. A 95th UCL was proposed as the input to emissions and dispersion modeling for chemicals and radionuclides. EPA (2008a) suggests that a simple mean of the asbestos data be used to estimate exposure point concentrations because of the lack of an established method for estimating a 95th UCL for asbestos. EPA also recommended that samples in which asbestos was not detected be evaluated using a value of zero and not ½ the analytical sensitivity. Both of these recommendations will be adopted for use in evaluating asbestos risks for site assessment areas at the Site. The uncertainty associated with these assumptions will be addressed by discussing the variability in the sample results and the risk implications of using other inputs, including the maximum detection, to characterize asbestos concentrations in soil.

4.3.3 Vapor Assessment

Inhalation exposures for vapors released from soils and groundwater will be evaluated for all worker and resident populations. Data applicable to vapor assessment could come from several different investigative techniques. Each technique has inherent uncertainties in predicting EPCs and associated inhalation risks. The use of multiple lines of evidence to assess the vapor pathway is considered the best way to reduce uncertainty in the assessment (ITRC 2007, USEPA 2008b). Accordingly, the vapor assessment for a site assessment area may be based on more than one line of evidence if supported by the data usability evaluation. The remainder of this section describes how data from each anticipated vapor investigation technique could be used to develop EPCs for the risk assessment.

4.3.3.1 Flux Chamber Data

Flux chamber data is obtained by placing an enclosure directly on the surface to be monitored and collecting vapors as they enter the chamber. Vapors can be collected by either a dynamic mode, in which a sweep gas is passed through the chamber to maintain a large concentration gradient across the surface being monitored, or a static mode for areas where vapor accumulation in the chamber is measured over time. Dynamic flux chamber testing has been conducted and used for vapor assessment at adjacent sites in the BMI Complex based on a collection procedure approved by NDEP (BRC 2008). This RAWP assumes that any flux chamber data available for vapor assessment at the Site will be collected in the same manner.

The results of the flux chamber testing are presented as a chemical-specific flux rate in units of mass over area and time (e.g., mg/m^2-sec). For use in the risk assessment, the chemical-specific flux rate must be converted to an air concentration. This conversion in made by linking the flux rate to a dispersion model that predicts the dilution of the vapors in the exposure environment relevant to the receptor population being evaluated.

For exposures assumed to occur outdoors in the ambient air (i.e., outdoor workers, construction workers, residents, trespassers) the default approach would be to link the flux rate data with a dilution factor developed by EPA (1996a) based on dispersion modeling that reflected annual average wind flow and mixing conditions for the Las Vegas, NV area. Because of the conservative nature of this default dilution factor, more refined site-specific modeling may be employed using EPA recommended air dispersion models. The chemical-specific flux rate used in the modeling would be calculated as the 95th UCL of all data collected within the site assessment area. The maximum flux rate measured for each chemical will also be reviewed as a means of bounding the uncertainty in the risk estimates based on the 95th UCL. Details on the equations used to calculate ambient air concentrations based on flux chamber data are provided in Appendix E.

For indoor worker exposures, the flux rate data would be linked to an indoor air model to estimate the indoor air concentrations. The ASTM (2004) provides an equation that combines the flux rate with parameters that balances the infiltration rate of the vapors into the indoor air and the volume and ventilation rate in the building to predict a steady-state air concentration. Default factors from ASTM (2004) will be used for assessing indoor air risks based on flux chamber data for this RAWP. The chemical-specific flux rate used in the modeling will be based on a 95th UCL for samples collected within the assumed building footprint. If the lateral dimensions of the flux chamber sampling locations for a site assessment area are larger than the assumed building footprint, then sampling locations will be grouped in to smaller units for calculation of 95% UCL values and used in the model to better represent the possible source area for the assumed building. The maximum flux rate measured within the site assessment area for each chemical will also be reviewed as a means of bounding the uncertainty in the risk estimates based on the 95th UCL. Details on the equations used to calculate indoor air concentrations based on flux chamber data are provided in Appendix E.

4.3.3.2 Soil Gas Data

There are a wide variety of soil gas sampling methods available; however, they can be divided into either active or passive methods. Passive methods involve burial of an absorbent material in the soil which collects vapors as they migrate through the soil column. Passive soil gas methods provide a measurement of the mass of a chemical that has diffused onto the absorbent material during the time they were buried. For use in a risk assessment, this measured mass would need to be converted to a vapor concentration. The conversion from mass to soil gas concentration is not well studied and validated methods are lacking. Therefore, passive soil gas sampling will not be used in a quantitative estimate of inhalation risk.

Active soil gas sampling consists of driving a probe into the soil and extracting a soil gas sample for laboratory analysis. The results of active soil gas sampling are reported as a concentration in units of mass over volume (e.g., mg/m^3). This soil vapor concentration must then be scaled to a representative air EPC for use in the risk assessment. EPCs would be required for ambient and

indoor air in order to evaluate the full range of receptors identified for the Site. Emissions and dispersion modeling will be conducted to scale the vapor concentrations to the appropriate inhalation EPCs. This modeling will be conducted separately for the indoor and ambient air exposures because of the differences in the infiltration rates and dilution that occur for vapors entering ambient versus indoor air.

For indoor air concentrations, the soil vapor concentration will be scaled through the use of attenuation factors. Indoor air exposures at the Site will be in commercial or industrial buildings. Default attenuation factors are available from the California Environmental Protection Agency (Cal/EPA) (2005) for commercial buildings. The default attenuation factors would be used with the maximum detected soil vapor concentration in the site assessment area to provide an initial screening of the potential inhalation health risks. For chemicals detected in soil gas that present an elevated health risk based on the initial screening, a more refined and site-specific approach based on the Johnson and Ettinger vapor intrusion model would be executed.

The Johnson and Ettinger vapor intrusion model has been used by EPA (2002b) for developing attenuation factors for soil gas infiltration into residential indoor air. The model predicts the rate of transport of volatile chemicals through the vadose zone and into indoor air. The transport through the vadose zone is a response to the concentration gradient modeled using Fick's First law. The diffusion in soil is described by an effective diffusion coefficient that is based on chemical-specific diffusivity values and soil porosity. At the interface of the vadose zone and building foundation, the Johnson and Ettinger model uses an approximation of the convective flux to estimate the rate at which the vapors would be drawn into the indoor air. The infiltration rate of vapors from the soil is balanced with the exfiltration rate of gases from the above-ground portion of the building to estimate the steady-state indoor air concentration.

Several versions of the Johnson and Ettinger model are available from EPA (2004b) depending on the nature of the source being modeled. The spreadsheet model developed for use with soil gas will be applied for this evaluation. Inputs will be a mixture of chemical and site-specific values along with recommended defaults from EPA (2004b). The model predicts a chemical-specific attenuation factor and associated indoor air concentration as a function of the input values, including soil gas concentration. The 95% UCL on the mean soil gas concentration for the site assessment area will be used as the input for the model calculations. If the lateral dimensions of the soil gas sampling locations for a site assessment area are larger than the assumed building footprint, then sampling locations will be grouped in to smaller units for calculation of 95% UCL values and used in the model to better represent the possible source area for the assumed building. Additionally, soil gas sampling results may be available from a variety of depths bgs. In most cases the shallowest soil gas concentration would be most relevant for modeling infiltration into indoor air. However, the full range of soil vapor data that passes through the data validation for the site assessment area will be considered in the risk

assessment. Additional details on the Johnson and Ettinger model and the input parameters can be found in Appendix E.

EPCs in ambient air associated with soil vapor concentrations will also be estimated using an emissions and dispersion modeling approach. A steady-state Fickian diffusion model will be used to predict the flux of vapors through the soil and into ambient air. The emissions model is based on an effective diffusion coefficient in soil and the distance the vapor must travel to reach the soil surface. The effective diffusion coefficient in soil is calculated from the chemical-specific air diffusivity values and soil porosity values. The input soil vapor concentration will be the 95th UCL soil gas concentration for the site assessment area. The range of vertical soil gas samples available for use in the risk assessment will be reviewed to determine the most relevant data to retain in the calculation of the 95th UCL.

The ambient air concentrations for vapors released from soil to ambient air will be estimated using the dispersion factor presented by EPA (1996a). The dispersion factor proposed for use in the risk assessment is based on meteorological data collected from Las Vegas, NV. The EPA (1996a) provides a range of dispersion factors depending on the size of the source area being evaluated. The available dispersion factor that is based on a source size that most closely matches the site assessment area being considered in a risk assessment will be selected. Details of the dispersion factor equation are provided in Appendix E.

4.3.3.3 Soil Data

Soil sampling data collected at the Site will be available for consideration in the vapor assessment. However, the soil vapor concentration for each chemical must be estimated using partitioning equations based on physicochemical parameters and soil conditions. This extrapolation requirement makes the use of soil data in vapor assessment less preferable to the direct measurement techniques discussed above (i.e., flux chamber and soil gas). Soil data may still be useful as a line of evidence to augment other direct measurement techniques for assessing soil vapor. If the data usability analysis for a site assessment area indicates that soil data are available, the following discussion summarizes how it could be used in the vapor assessment.

For outdoor workers, residents and construction workers, the soil data could be used to estimate exposures based on the soil volatilization model provided in the EPA *Soil Screening Guidance* (USEPA 1996a). For indoor workers the soil data could be used to estimate exposure exposure will be based on the Johnson and Ettinger model of vapor intrusion. Each of the volatilization models is described in the following text.

For outdoor workers, residents and construction workers, the inhalation exposure to volatile chemicals released from soil will be conducted using a volatilization factor (VF) approach. Like the PEF, the VF is composed of an emission component and a dispersion component. The

volatilization component is based on a time-dependent equilibrium model that assumes an infinite source of contamination. An average flux rate would be calculated by integrating the time-dependent model over the exposure period assumed for each receptor. The AT used in the model will match the ED for all receptors with the exception of subchronic exposures assumed for construction workers (i.e., less than 7 years). For subchronic exposures the AT will be set to 6 years to avoid overestimation of the emissions that would occur by assuming a shorter AT. Modeling with shorter ATs would in effect reflect a fresh spill rather than the older residual sources of contamination at the Site. Site-specific values will be used for the soil characteristics related to porosity and density. Chemical-specific soil concentrations based on the 95th UCL for the upper portion of the vadose zone in the site assessment area. Appendix E provides a summary of the model equations and input values.

The dispersion factor portion of the VF model for outdoor exposures is based on air modeling conducted for a range of source sizes and climatic regions throughout the United States. We propose to use the dispersion factor developed by EPA (1996a) using meteorological data for Las Vegas, NV. In addition, we will modify the dispersion factor to reflect the area of the site assessment area which is the assumed to represent the source extent for the emissions modeling.

The flux rate of chemicals from the soil can be increased due to soils handling activities related to construction. EPA (2002a) has determined that the conservative nature of the infinite source model used to model volatilization from soil, which assumes that volatile contaminants are present at the soil surface, should be protective of offsite residents, even for periods of construction activities. A sensitivity analysis will be conducted to determine the potential increase in exposure and risk estimates based on the potential increase in the flux rate during construction activities. The sensitivity analysis will also compare the model predictions to other volatilization-related studies conducted within the immediate vicinity of the Site as a means to evaluate the uncertainty in the risk estimates.

For onsite indoor workers the inhalation exposure related to release of volatile organic chemicals in soil will be evaluated using the EPA's Johnson and Ettinger model (USEPA 2004b). The model to be used for the risk assessment is contained in spreadsheets available from EPA. For this application the version that deals with soil sources will be used. The Johnson and Ettinger models available from EPA contain defaults for all of the physical parameter values needed to conduct the modeling. We propose to use site-specific parameters for physical properties required to describe soil and groundwater properties (e.g., porosity, vadose zone temperature, depth of soil contamination). The default building characteristics contained in the EPA Johnson and Ettinger models will be used in this evaluation. These include parameters such as vapor flow rate into the building, the building lateral footprint, indoor mixing height, and air exchange rate.

The input soil concentration for the COPCs evaluated in the vapor intrusion model will be based on the 95th UCL soil concentrations found in the upper vadose zone of the site assessment area. A sensitivity analysis will be conducted for the model inputs to evaluate the uncertainty in the risk estimates. A detailed discussion of the model and the input parameters, are presented in Appendix E.

4.3.3.4 Groundwater Data

Groundwater data are also available for the Site and could be used as a line of evidence in the vapor assessment. Inhalation exposures to volatile chemicals in onsite groundwater could be evaluated for all worker and resident populations. For outdoor workers, residents and construction workers, the exposures will be based on the groundwater volatilization model provided in the EPA *Soil Screening Guidance* (USEPA 1996a). For indoor workers the exposure will be based on the Johnson and Ettinger model of vapor intrusion. Each of the volatilization models is described in the following text.

For outdoor workers, offsite residents and construction workers, inhalation exposures to volatile chemicals released from groundwater are assumed to occur in ambient air. A VF approach will be used to characterize this exposure. The volatilization model is a steady-state equilibrium model that describes the transport of vapors through the vadose zone and into ambient air. The model assumes that groundwater is the source of the vapors in the vadose zone and not the soil column. The movement of the vapor is calculated based on Fick's first law. The diffusion is in response to the concentration gradient across the vadose zone and can be described by an effective diffusion coefficient. The total effective diffusion coefficient will be calculated based on a two component approach, as used in the soil vapor intrusion modeling via the Johnson and Ettinger model. The first component described is the effective diffusion across the capillary zone, and the second component reflects movement in the vadose zone.

The dispersion factor for groundwater volatilization to ambient air will be based on a dilution factor presented by EPA (1996a). The dilution factor was based on the modeling conducted using the Industrial Source Complex air dispersion model. The air dispersion model was run for a range of square area sources from 0.5 acres to 30 acres in size. A unit flux rate (i.e., 1 g/m^2-sec) was used in the model to generate normalized ambient air concentrations at the center of the source area (i.e., kg/m^3 per g/m^2-sec). The normalized air concentrations will be used with site-specific volatilization flux rates to yield the associated ambient air concentrations. Normalized ambient air concentrations were calculated for 29 locations throughout the United States, including Las Vegas, NV. The model results for Las Vegas, NV will be used in this risk assessment. The dilution factor selected for use in the risk assessment will be adjusted to reflect the area of the relevant groundwater source at the Site. The volatilization and dispersion factors will be combined to develop the volatilization factor for the groundwater to ambient air pathway. Details of the equations and inputs to be used for exposure pathway are presented in Appendix E.

For onsite indoor workers the infiltration of volatile chemicals from groundwater into indoor air will be evaluated using EPA's Johnson and Ettinger model (USEPA 2004b). The model predicts the rate of transport of volatile chemicals through the vadose zone and into indoor air. The transport through the vadose zone is modeled as a response to the concentration gradient using Fick's First law. The diffusion is described by an effective diffusion coefficient that is based on chemical-specific diffusivity values and soil porosity. At the interface of the vadose zone and building foundation, the Johnson and Ettinger model uses an approximation of the convective flux to estimate the rate at which the vapors would be drawn into the indoor air. The infiltration rate of vapors from the soil is balanced with the exfiltration rate of gases from the above-ground portion of the building to estimate the steady-state indoor air concentration.

The model to be used for the risk assessment is contained in spreadsheets available from EPA. For this application the version that deals with groundwater sources will be used. The Johnson and Ettinger models available from EPA contain defaults for all of the physical parameter values needed to conduct the modeling. We propose to use site-specific parameters for physical properties required to describe soil and groundwater properties (e.g., porosity, vadose zone temperature, depth to groundwater). The default building characteristics contained in the EPA Johnson and Ettinger models will be used in this evaluation. This includes parameters such as vapor flow rate into the building, the building lateral footprint, indoor mixing height, and air exchange rate.

The input groundwater concentration for the COPCs evaluated in the vapor intrusion model will be based on the 95th UCL for concentrations found within the site assessment area area. A sensitivity analysis will be conducted for the model inputs to evaluate the uncertainty in the risk estimates. This analysis will include consideration of localized areas of elevated groundwater concentrations relative to the 95th UCL based on all data within the site assessment area. A complete listing of the inputs values for the model parameters, except for chemical-specific parameters, is presented in Appendix E.

5 TOXICITY ASSESSMENT

The purpose of a toxicity assessment is to summarize health effects that may be associated with exposure to the constituents included in the risk assessment and to identify doses that may be associated with those effects. The focus of the toxicity assessment will be on effects associated with repeated long-term exposures and on effects that could be associated with the chemical and radionuclide concentrations and pathways of exposure that are relevant for this Site. Toxicity values developed based on dose-response assessments for these relevant adverse effects will be identified. These toxicity values are numerical expressions of dose and response, and vary based on factors such as the route of exposure (e.g., oral or inhalation) and duration of exposure (e.g., subchronic, chronic).

In assessing the potential toxicity of chemicals and radionuclides, duration of exposure is an important factor because the exposure levels that can cause toxic effects are usually lower when exposures continue for a longer period of time. For example, with continuous exposure to a chemical for many years (typically referred to as chronic exposure), much lower concentrations (and resulting doses) of a chemical could be associated with toxic effects, compared with concentrations that would be identified as causing toxic effects in a person who is exposed to a chemical for only one day (referred to as an acute exposure). Intermediate duration exposures (referred to as subchronic exposures) are more likely to suggest toxic effects at intermediate concentrations. The risk assessments will evaluate risks associated with scenarios involving subchronic and chronic exposures to COPCs on and around the Site; acute exposures will not be evaluated quantitatively.

The following section describes the procedures that will be used to identify and assess toxicity information. Additional discussion is provided for the approach used to assess the toxicity of mixtures of dioxins/furans and carcinogenic polycyclic aromatic hydrocarbons (PAHs), and asbestos.

5.1 METHODS FOR TOXICITY ASSESSMENT

Standard procedures, per EPA (1989 and others) will be followed to identify and assess toxicity factors and other relevant toxicity information, such as the weight-of-evidence (WOE) category for carcinogenic potential. As recommended in the EPA memorandum, *Human Health Toxicity Values in Superfund Risk Assessments* (USEPA 2003b), the primary sources that will be consulted for toxicity values are, in order of priority, EPA's Integrated Risk Information System (IRIS; USEPA 2007a) and EPA's provisional peer reviewed toxicity values (PPRTVs) from the National Center for Environmental Assessment/Superfund Health Risk Technical Support Center. If neither IRIS toxicity values nor PPRTVs are available, then toxicity values will be obtained from other documented sources, such EPA's Health Effects Assessment Summary Tables (HEAST;

USEPA 1997b), the Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs; ATSDR 2007), and Oak Ridge National Laboratory's Risk Assessment Information System (ORNL, RAIS; USDOE 2007). Toxicity values appropriate to the relevant exposure routes (e.g., oral, inhalation) and exposure times (e.g., subchronic, chronic) determined for the risk assessment will be collected from these sources.

In addition to these sources, human health toxicity criteria developed by Integral Consulting (Integral) for five organic acid SRCs will be used. The toxicity criteria developed by Integral for diethyl phosphorodithioc acid (DEPT) and dimethyl phosphorodithioic acid (DMPT) were submitted and approved with modification by NDEP in 2007 (Integral 2006; NDEP 2007). The toxicity criteria developed for 4-chlorobenzene sulfonic acid (pCBSA), benzenesulphonic acid (BSA), and phthalic acid were submitted to NDEP in November 2007 (Integral 2007) and approved by NDEP in 2008 (NDEP 2008i,j). The final NDEP-approved values will be used in the risk assessment. Following NDEP guidance (NDEP 2009d), the noncarcinogenic toxicity criterion for dichlorbenzil will be based on the toxicity criterion for 4,4'-dichlorobenzophenone (DCBP), adjusted with additional uncertainty factors to account for the likely greater environmental persistence of dichlorobenzil compared to the surrogate, and for database deficiencies. Additionally, in line with NDEP guidance (NDEP 2006c) pyrene will be used as a toxicological surrogate for noncancer toxicity endpoints for PAHs where no noncancer toxicity criterion are available from EPA or the alternative sources listed above. As recommended by NDEP, the noncarcinogenic toxicity criterion for pyrene will be adopted for the following PAHs: benzo(a)anthracene, benzo(a)pyrene (BaP), benzo(b)fluoranthene, benzo(k) fluoranthene, chrysene, dibenzo(a,h)anthracene, indeno(1,2,3-c,d)pyrene, acenaphthylene, benzo(g,h,i)perylene, and phenanthrene.

Route-to-route extrapolation assumes that once a chemical is absorbed into the bloodstream, the health effects are similar regardless of whether the route of exposure is oral, dermal, or inhalation. This assumption may be valid for some chemicals with pharmacokinetic characteristics that are similar regardless of route of administration; however, for many chemicals, factors such as absorption, metabolism, distribution, and elimination vary by exposure route, leading to substantial differences in toxicity. Typically, EPA recommends using route-to-route extrapolation to address assess risks from absorbed dose following dermal exposures and these recommendations will be followed here, and discussed in the following sections.

EPA (2009a) explicitly warns against extrapolating oral toxicity criteria to inhalation values because the amount of the chemical that reaches the target site through the inhalation pathway is not a simple function of known parameters (i.e., BW, inhalation rate), but rather a complicated set of factors including the physiochemical characteristics of the inhaled contaminant and human physiologic parameters. Therefore, consistent with EPA (2009a) guidance, route-to-route extrapolations will not be conducted to assess inhalation exposures for most chemicals. The only exceptions to this are cases in which EPA has published inhalation

toxicity values that were generated using route-to-route extrapolations. Again, consistent with EPA (2009a) guidance, these values will be used in the risk assessment without adjustment.

In the case that toxicity criteria are not available for a COPC specific to the exposure route being evaluated a quantitative evaluation of risks associated with exposure to the COPC will not be completed. Uncertainties associated with the exclusion of these COPCs from the quantitative risk evaluation will be discussed in the uncertainty section, as relevant.

The following two subsections describe the toxicity values used to assess noncancer and carcinogenic effects of chemicals including radioactive constituents.

5.1.1 Noncancer Effects from Chemical Exposures

The potential for noncancer health effects from chronic exposures (i.e., greater than 7 years) will be evaluated by comparing the estimated daily intake with a reference dose (RfD) for oral exposure routes, and a reference concentration (RfC) for inhalation exposure routes. Chronic toxicity values represent average daily exposure levels at which no adverse health effects are expected to occur with chronic exposures. Subchronic RfDs/RfCs represent average daily exposure levels at which no adverse health effects are expected to occur with subchronic exposures of less than 7 years, as would be the case for the construction worker and trespasser scenarios to be evaluated for the site. RfDs/RfCs reflect the underlying assumption that systemic toxicity occurs as a result of processes that have a threshold.

The RfDs/RfCs for many noncarcinogenic effects are generally derived based on laboratory animal studies or epidemiological studies in humans. In such studies, the RfD/RfC is typically calculated by identifying the highest concentration or dose that does not cause observable adverse effects (the no-observed-adverse-effects level or NOAEL) in the study subject. If a NOAEL cannot be identified from the study, a lowest-observed-adverse-effects level (LOAEL) may be used. This dose or concentration is then divided by uncertainty factors to calculate an RfD/RfC.

Uncertainty factors are applied to account for limitations of the underlying data and are intended to ensure that the toxicity value calculated based on the data will be unlikely to result in adverse health effects in exposed human populations. For example, an uncertainty factor of 10 is used to account for interspecies differences (if animal studies were used as the basis for the calculation), and another factor of 10 is used to address the potential that human subpopulations such as children or the elderly may have increased sensitivity to the chemical's adverse effects. Thus, variations in the strength of the underlying data are reflected in the uncertainty factors used to calculate the toxicity values and in the low, medium, or high confidence ratings assigned to those values (USEPA 2007a).

For cases in which toxicity values are not available for the specific time-frame, or exposure route being evaluated, in some instances existing values for other time-frames or routes may be used.

For example, EPA states that in cases in which a reference value for a desired duration period (e.g., subchronic) is not available, a reference value based on the next longer duration of exposure may be used as a conservative estimate that would be protective for the shorter-term ED (USEPA 2009a). This procedure will be adopted for the risk assessments.

RfDs are not available for assessing the dermal exposure route. Oral toxicity values are typically used instead. Because oral toxicity values are usually derived from administered doses, while dermal exposure estimates are expressed as absorbed doses, the oral toxicity values must be adjusted to reflect absorbed dose. This adjustment is accomplished by multiplying the oral RfD by a chemical-specific oral absorption rate. The chemical-specific oral absorption rate is an expression of the fraction of contaminant absorbed in the gastrointestinal (GI) tract in the critical toxicity study. This procedure will be used in the risk assessment. GI absorption values (ABS_{GI}) will be obtained from EPA's *RAGS Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA 2004a), NDEP guidance (NDEP 2008k) and the ORNL RAIS (2007). Following EPA guidance (2004a) toxicity criteria for chemicals with an ABS_{GI} less than 50 percent will be adjusted.

A summary of toxicity for each COPC will include the chronic and subchronic RfD or RfC, as well as the target organ of toxicity and uncertainty factors used in deriving the RfD/RfC. Uncertainties in the toxicity values will additionally be described.

5.1.2 Carcinogenic Effects from Chemical Exposures

To assess carcinogenic health effects, CSFs are used for oral and dermal exposures, while inhalation unit risks (IURs) are used for inhalation exposures. CSFs and IURs are upper-bound estimates of the carcinogenic potency of chemicals. They are used to estimate the incremental risk of developing cancer, corresponding to a lifetime of exposure at the levels described in the exposure assessment. In standard risk assessment procedures, estimates of carcinogenic potency reflect the conservative assumption that no threshold exists for carcinogenic effects (i.e., that any exposure to a carcinogenic chemical will contribute an incremental amount to an individual's overall risk of developing cancer).

Another component of assessing carcinogenic health effects is a qualitative evaluation of the extent to which a chemical is a human carcinogen. For many chemicals listed in IRIS, this evaluation was conducted by EPA using a classification system for WOE determination.[8] A chemical is assigned a WOE classification based on data obtained from both human and animal studies. Chemicals for which EPA considers adequate human data indicating carcinogenicity are available are categorized as "known human carcinogens" (WOE class A), while other

[8] The WOE categories described in the final *Guidelines for Carcinogen Risk Assessment* (USEPA 2005) as "standard hazard descriptors" differ from and may eventually supersede those used in IRIS (USEPA 2007a). These descriptors include "carcinogenic to humans," "likely to be carcinogenic to humans," "suggestive evidence of carcinogenic potential," "inadequate information to assess carcinogenic potential," and "not likely to be carcinogenic to humans."

chemicals with various levels of supporting data may be classified as "probable human carcinogens" (WOE class B1 or B2), or "possible human carcinogens" (WOE class C). Where EPA considers that data are inadequate for determining carcinogenicity, the chemical is "not classifiable as to human carcinogenicity" (WOE class D). When studies provide evidence of noncarcinogenicity, a chemical is assigned a WOE class E (USEPA 2007a).

As described for noncarcinogens, toxicity values measuring carcinogenic potency are not readily available for the dermal exposure route. Following EPA guidance, oral CSFs for chemicals with ABS_{GI} less than 50 percent will be adjusted to determine dermal CSFs. ABS_{GI} will be obtained from EPA's *RAGS Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (2004a), NDEP guidance (2008k), and the ORNL RAIS (2007).

A summary of toxicity for each COPC will include the qualitative WOE classification and the CSF or URF. Uncertainties in the incremental risk values will additionally be described.

5.1.3 Effects from Radionuclides

Biological effects associated with exposure to ionizing radiation in the environment may include carcinogenicity, mutagenicity, and teratogenicity. EPA (2001) has determined that cancer risk is the most significant health effect potentially associated with exposure to radionuclides[9]. EPA classifies all radionuclides as WOE class A, based on their property of emitting ionizing radiation and on the WOE provided by epidemiological studies of radiogenic cancers in humans (USEPA 2001, 2009b).

CSFs for radionuclides are available from HEAST for specific ingestion, inhalation, and external exposures (USEPA 2001, 2009b). The CSFs are derived using models that take into account age- and gender-dependence of radionuclide intake, metabolism, dosimetry, radiogenic risk, and competing causes of death. The model averages the risk over the lifetime of the exposed individual. Consequently the slope factors are not expressed as a function of BW and time.

The resultant CSFs represent central estimates of age-averaged, excess lifetime cancer incidence per unit of activity of a given radionuclide inhaled or ingested, for internal exposure, or per unit time-integrated activity concentration in air or soil for external exposure for an average member of the reference population[10]. The CSFs may be used to estimate the lifetime cancer incidence risk attributable to a given radionuclide exposure for an average member of the population, but

[9] The only exception to this is uranium, which presents both noncarcinogenic chemical hazard and carcinogenic radiological risks. In line with EPA guidance (USEPA 1996b) in the case that uranium is selected as a COPC for a risk assessment, both types of risk will be evaluated. Noncarcinogenic health effects will be evaluated as for other noncarcinogenic chemicals using toxicity criteria specific to uranium.
[10] Current values were calculated using characteristics, mortality statistics, and baseline cancer rates from the 1980s U.S. population

are not appropriate for assessing the risk to a single individual of a particular age or gender. In addition to the age-averaged values, for the soil ingestion pathway, an adult only CSF is available from HEAST.

All radionuclides undergo decay in which the parent radionuclide is transformed in atomic number, mass, or excitation state. In some cases the resulting decay products are radioactive, and may undergo further decay. Each of these decay products may have different physical and chemical properties which affect their environmental fate and transport, as well as different toxic characteristics and potencies. Because each is unique in its action and toxicity, consideration of all of the decay products is a key element in the risk assessment process. The radiation dose estimates used to calculate the radionuclide CSFs explicitly consider the production of radioactive decay products within the body following ingestion or inhalation; however, only intake or external exposure to the single radionuclide is considered. For certain radionuclides with decay products where contributions of dose and risk from radioactive decay products may be significant, EPA has derived CSFs which incorporate the contribution of short-term decay chain products (i.e., less than 1 year half-life) to the total risk. The resultant CSFs are higher (more conservative) than those which consider the parent radionuclide only, because they additionally consider the risk contribution from the short-lived decay products. The calculation of the CSF from these decay chains assumes the presence of SE.

The CSFs from HEAST will be used to evaluate risks to populations with completed exposures at the Site. The adult only CSF for soil ingestion will be utilized for scenarios where exposure occurs within adulthood only (e.g., worker populations). For all other receptor populations and completed exposure pathways, the age-averaged CSFs will be used. Given that the difference between the age and gender-averaged risk coefficients and the adult-only risk coefficients are slight, the use of the age-averaged values are considered appropriate for evaluating risks to adults. The evaluation of SE, described in Section 3.4.3.1, will be used to select the CSFs used; in the case that SE exists, the CSF which includes the contribution of short-term decay products will be selected. Where SE does not exist, the choice of CSFs will depend on the analytical data available for the parent and decay products. Any significant uncertainties resulting from the use of an age adjusted CSF, or CSFs which incorporate, or do not incorporate decay products will be discussed in the risk assessments.

5.1.4 Effects from Asbestos

Asbestos risks will be assessed using the same approach as used in risk assessments conducted at sites within the overall BMI Complex. This approach relies on exposure-response coefficients that relate the toxicity of different fiber lengths and types of asbestos to each other. These risk coefficients are outlined in the draft, *Technical Support Documents for a Protocol to Assess Asbestos Related Risk* (USEPA 2003c) and are presented below. In the case that activity based sampling for asbestos is completed in the future, the unit risk factors outlined in EPA's *Framework for Investigating Asbestos-Contaminated Superfund Sites* (USEPA 2008a) will be adopted.

The majority of available information indicates that lung cancer and mesothelioma are the most important risks associated with low levels of asbestos (USEPA 2003c). Types and aspect ratios (relative length versus diameter) of asbestos fibers differ, and are known to affect the potency of the material; therefore, deriving conclusions regarding the health effects related to asbestos exposure is complex. In the draft document (USEPA 2003c) EPA reviewed studies from environments with asbestos dusts of differing characteristics to evaluate asbestos related risks. EPA developed an optimal exposure index, which best reconciles the published literature. The index assigns equal potency to fibers longer than 10 μm and thinner than 0.4 μm and assigns no potency to fibers of other dimensions. The optimal exposure index also assigns unique exposure-response coefficients for chrysotile and amphibole fibers for the endpoints of mesothelioma and lung cancer. Optimum dose response coefficients, based on the body of available data will be assumed for this risk assessment. The coefficients are presented in Appendix F.

5.2 APPROACHES FOR CHEMICAL MIXTURES

For some groups of chemicals, such as polychlorinated dibenzo-p-dioxins (PCDDs)/polychlorinated dibenzofurans (PCDFs) and PAHs, information on the toxic potency of individual constituents of the group are expressed in relative terms. The approaches for evaluating PCDDs/PCDFs and PAHs are described below.

5.2.1 Toxicity Equivalency Approach for PCDDs/PCDFs

Dioxins and furans (PCDDs and PCDFs) are two groups of structurally similar, tricyclic, almost planar, organic compounds that exhibit similar physical and chemical properties. There are 75 dioxins and 135 furans, called congeners, which are differentiated by their number and position of chlorine atoms. Researchers in the early 1980s concluded that a subset of PCDDs, PCDFs, and PCB congeners shared a common mechanism of action and induced comparable biological and toxic responses (USEPA 2003d). However, the potency of the different congeners varies considerably.

Seventeen PCDD and PCDF congeners (7 PCDDs, 10 PCDFs) exhibit what is termed "dioxin-like" toxicity. These 17 congeners have chlorine atoms present in the 2, 3, 7, and 8 positions on the ring structure of the molecule and are more toxic than other congeners with fewer chlorine atoms or with chlorine atoms in different positions on the ring structure. The congener 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) is the most widely studied and has been found to exhibit the most potent toxic response. Similarly, 12 coplanar PCB congeners have been shown to exhibit dioxin-like toxicity and are grouped with the 17 dioxin/furan congeners that exhibit toxicity similar to TCDD (USEPA 2007b).

Human health risk estimates for exposures to PCDDs/PCDFs traditionally require conversion of concentrations of individual dioxin and furan congeners to their 2,3,7,8-TCDD toxic equivalent (TEQ) concentration using congener-specific toxic equivalency factors (TEFs). The 2,3,7,8 – TCDD TEQ concentration for each sample is calculated by multiplying concentrations of individual congeners by their congener-specific TEFs, and summing the results for all congeners as shown in Equation 5-1, below. The 2,3,7,8-TCDD TEQ concentration is assumed to express the total potency of the mixture of PCDDs/PCDFs in a sample to exert the toxicity of 2,3,7,8-TCDD.

$$TEQ = \Sigma(C_1 \times TEF_1) + (C_2 \times TEF_2)...(C_n \times TEF_n) \qquad \text{Eq. 5-1}$$

where,

C = Congener specific concentration (e.g., mg/kg)

TEF = Congener specific TEF (unitless).

For assessment of human health risks, TEFs developed by the World Health Organization (WHO) (Van den Berg et al. 1998) and adopted by NDEP for deriving BCLs (NDEP 2009e) will be to calculate TEQs. These TEFs are the most widely accepted equivalency factors and are typically expressed as "WHO98 TEFs". Table 5-1 presents the TEFs that will be used in the risk assessment.

Risk from TEQ concentrations are calculated similarly to that from other COPCs by combining calculated exposure with a risk-based criteria.

5.2.2 Relative Potency Approach for PAHs

The cancer potencies of individual carcinogenic PAH chemicals are expressed relative to the cancer potency of BaP. This procedure involves applying chemical-specific relative potency factors (RPFs) to the CSF for BaP, resulting in a CSF adjusted for the toxicity of each PAH relative to BaP. Table 5-1 presents the RPFs provided by EPA (1993) that will be used in the risk assessment if PAHs are selected as a COPC.

Risks associated with PAHs will be evaluated in a compound specific manner using toxicity criteria based on the RPFs outlined above. In order to retain the ability to more fully understand the contributions of various PAHs to estimates of risk, the individual PAHs for a given sample will not be summed in an *a priori* manner. However, to avoid reducing the effects of multiple PAHs that may act via a similar mode of action, in the case that any single carcinogenic PAH is selected as a COPC, the full suite of carcinogenic PAHs will be evaluated using ½ the SQL for non-detects. This could in certain situations lead to risks that are

dominated by non-detect values. If this occurs, the uncertainty associated with this approach will be discussed in the risk report.

Despite the wide use of RPFs in health risk assessments at Superfund and Resource Conservation and Recovery Act (RCRA) sites to express the toxicity of carcinogenic PAHs in relation to the toxicity of BaP, numerous limitations of its use have been identified. These limitations contribute to uncertainty in the estimation of risks for the Site. The uncertainties associated with this approach will be discussed in the risk assessment.

6 RISK CHARACTERIZATION

The goal of risk characterization is to present and interpret the key findings of the risk assessment, along with their limitations and uncertainties, for use in risk management decision making. In the process of risk characterization, quantitative estimates of exposure and toxicity are compared to yield estimates of potential health risk. Risks for noncancer and cancer effects are estimated separately because of differences in calculation methods.

This section describes the methods that will be used for quantifying and interpreting risks and for characterizing uncertainties associated with the risk estimates.

6.1 NONCANCER RISKS FROM CHEMICAL EXPOSURES

Health risks other than cancer are characterized as the increased likelihood that an individual will suffer adverse health effects as a result of chemical exposure. To evaluate noncancer risks, the ratio of the exposure term (i.e., average daily intake or EC) to the corresponding noncarcinogenic toxicity reference value (i.e., RfD or RfC) is calculated. It is most appropriate to apply reference values that correspond with the duration of exposure assumed for a specific receptor should be applied (e.g., where ED is less than 7 years, a subchronic RfD or RfC is ideally used). This ratio is referred to as the HQ. If the calculated value of the HQ is less than or equal to 1, no adverse health effects are expected. If the calculated value of the HQ is greater than 1, then further risk evaluation is needed.

The HQ is calculated for oral and dermal exposure pathways using the following equation:

$$HQ(unitless) = \frac{ADD}{RfD} \qquad \text{Eq. 6-1}$$

where,

ADD[11] = average daily dose of the chemical via the specified exposure route (mg/kg-day)

RfD = reference dose (mg/kg-day).

The HQ is calculated for the inhalation exposure pathway using the following equation:

[11] For exposure via dermal contact, the ADD is referred to as the dermally absorbed dose (DAD); however, for simplicity, intakes are referred to as the ADD for all exposure routes.

$$HQ(unitless) = \frac{EC}{RfC} \qquad \text{Eq. 6-2}$$

where,

EC = exposure concentration (μg/m^3)

RfC = reference concentration (μg/m^3).

To evaluate the effect of exposure to multiple chemicals that act on the body in a similar manner, the HQs for each exposure pathway for individual chemicals are typically summed to determine a noncancer hazard index (HI) using the following formula:

$$HI(unitless) = HQ_1 + HQ_2 + ... + HQ_i \qquad \text{Eq. 6-3}$$

where,

HQ = hazard quotient for specified exposure pathway (unitless).

HIs for multiple chemicals are generally not summed if the reference doses for the chemicals are based on effects on different target organs. This is because the noncancer health risks associated with chemicals that affect different target organs are not likely to be additive. For this reason, in the case that the total HI exceeds 1 for all COPCs combined, a more refined analysis based on target organ may be conducted.

6.2 CANCER RISKS FROM CHEMICAL EXPOSURES

The cancer risk estimates derived using standard risk assessment methods are characterized as the incremental probability that an individual will develop cancer during his or her lifetime due to exposure to SRCs resulting from the specific exposure scenarios that are going to be evaluated. The term "incremental" reflects the fact that the calculated risk associated with site-related exposure is in addition to the background risk of cancer experienced by all individuals in the course of daily life.

Excess incremental lifetime cancer risks are calculated as the product of the exposure term (i.e., lifetime average daily intake or EC) and the expression of the carcinogenic potency of chemicals (i.e., CSF or IUR).

Excess incremental lifetime cancer risk from oral and dermal exposures is calculated using the following equation:

$$Cancer\ Risk(unitless) = LADD \times CSF \qquad \text{Eq. 6-4}$$

where,

LADD = lifetime average daily dose of the chemical via the specified exposure route (mg/kg-day)

CSF = cancer slope factor (kg-day/mg).

Excess incremental lifetime cancer risk from inhalation exposures is calculated using the following equation:

$$Cancer\ Risk(unitless) = EC \times IUR \qquad \text{Eq. 6-5}$$

where,

EC = exposure concentration ($\mu g/m^3$)

IUR = inhalation unit risk ($m^3/\mu g$).

6.3 RADIONUCLIDE RISKS

Cancer risks resulting from intakes of radionuclides are calculated in a similar manner to cancer risks for chemicals. The primary difference in the characterization is that equations used to characterize risks from radionuclides rely on intake parameters, and risk coefficients, expressed in units of activity.

For internal exposure excess cancer risk will be calculated as:

$$Cancer\ Risk(unitless) = Dose \times CSF \qquad \text{Eq. 6-6}$$

where,

Dose = total dose of a radionuclide via the specified exposure route (pCi)

CSF = cancer slope factor (pCi^{-1}).

For external exposure excess cancer risk will be calculated as:

$$Cancer\ Risk(unitless) = EET \times CSF \qquad \text{Eq. 6-7}$$

where,

EET = external exposure term for a radionuclide (pCi – yr/g)

CSF = cancer slope factor (g/pCi - yr).

Because cancer risks are assumed to be additive, risks associated with simultaneous exposure to more than one carcinogen (chemicals and radionuclides) in a given medium are typically combined to estimate the total cancer risk associated with each exposure pathway (USEPA 1989). Where exposures may occur via multiple exposure routes, total cancer risks for each exposure pathway will be summed for reasonable combinations of exposure pathways to determine the total cancer risk for the population of concern.

6.4 LEAD RISKS

In the case that lead analytical results exceed the NDEP BCL of 800 mg/kg, the ALM will be used to estimate risks associated with lead exposure. The ALM predicts the blood lead level in an adult with a site-related lead exposure by summing the "baseline" blood lead level (PbB_0) (i.e., that which would occur in the absence of any site-related exposures) with the increment in blood lead concentration that is expected as a result of increased exposure due to contact with lead-contaminated soil at the Site (USEPA 2003a). According to EPA (2003a), protection of the fetus is the most health-sensitive endpoint for adults. In-line with assessing this endpoint the ALM includes a module to predict fetal blood lead levels. In the case that the ALM is applied, following EPA guidance (2003a) central estimates of exposure will be used in the model. The arithmetic mean EPC will be used in the model. Baseline blood lead concentrations and geometric standard deviations of blood lead for the ALM will be obtained from US population data presented in the National Health and Nutrition Examination Survey (NHANES) III. A target risk level of no more than a five percent probability that a fetus exposed to lead will exceed a blood lead level of 10 μg/dL will be applied as the risk threshold.

6.5 ASBESTOS RISKS

Both chrysotile and amphibole fibers have been detected at the Site, and therefore both will be evaluated in the risk assessment.

Consistent with risk assessments conducted at sites within the overall BMI complex, risks associated with asbestos will be evaluated using EPA (2003c) draft protocol assessment methodology. This methodology details procedures to calculate the risk of additional deaths from lung cancer and mesothelioma from inhalation exposures to asbestos and is discussed in detail below. In the case that activity-based sampling for asbestos is completed in the future,

the approach outlined in EPA's Framework for Investigating Asbestos-Contaminated Superfund Sites (EPA 2008a) will be adopted.

Under the EPA (2003c) approach for evaluating asbestos-related cancer risk, risk is estimated as the product of a risk coefficient and a mathematical function that depends on the level of exposure, the duration of exposure, and time. Estimates of additional deaths attributable to asbestos from lung cancer, from mesothelioma, and from both combined, are based on the optimum risk coefficients, described in Section 5.4. The risks presented represent risks attributable to lifetime, continuous exposure to an asbestos concentration of 0.0001 f/cm^3 (for fibrous structures longer than 10 µm and thinner than 0.4 µm) as determined using transmission electron microscopy (TEM) methods.

Following EPA (2003c) guidance, in order to estimate site-specific risks, risk estimates described above will be multiplied by the estimate of airborne concentration (CTE and RME) and divided by 0.0001. This calculation assumes that the additional risk of death is proportional to the asbestos exposure level.

Lifetime asbestos induced risk of both lung cancer and mesothelioma differ between males and females, and smokers and non-smokers. Risk estimates for each of these subgroups will be combined with population statistics to determine a population averaged risk using the following equation (Eq. 8-1, USEPA 2003c):

$$R_{avg} = 0.5 \times [0.214 \times (MS + FS) + 0.786 \times (MNS + FNS)] \qquad \text{Eq. 6-8}$$

where,

R_{avg}	=	population averaged risk for the chosen disease endpoint
MS	=	corresponding risk for male smokers
FS	=	corresponding risk for female smokers
MNS	=	corresponding risk for male non-smokers
FNS	=	corresponding risk for female non-smokers.

Risks of additional deaths by sub-population to be used for the risk calculations are included in Appendix F. The combined risks of lung cancer and mesothelioma will be calculated.

6.6 UNCERTAINTY EVALUATION

The final element of the risk assessments will be an assessment of the uncertainty in the estimated noncarcinogenic and carcinogenic risks. Uncertainty is inherent in many aspects of the risk assessment process, and generally arises from a lack of knowledge of 1) site conditions and future site use, 2) toxicity and dose-response for COPCs, 3) the extent to which an individual may be exposed to COPCs, and/or 4) the representativeness of modeled exposure

point concentrations. This lack of knowledge means that assumptions must be made based on information presented in the scientific literature or professional judgment. In general, such assumptions will be made in a manner that intentionally biases the process towards health protection.

Uncertainties in the risk will be identified and addressed qualitatively in general, although some quantitative measures of uncertainty (e.g., probabilistic analyses using Monte Carlo analysis) may be provided. Descriptions of the uncertainty inherent in analytical data and toxicity and exposure parameters used to characterize risks will be provided in the risk assessment reports. The uncertainty analyses will conclude with a discussion of the overall impact of uncertainty in the risk assessment on the risk characterization for the Site.

6.7 PRESENTATION AND INTERPRETATION OF FINDINGS

The risk assessments results will be presented in tabular format and include key supporting information used to calculate the risks. Key pathways and COPCs that drive risk estimates will be identified and discussed. Reports will include discussions of the results in the context of their implications for risk management actions at the Site. Key uncertainties or data gaps and their influence on risk management decisions also will be discussed. Risk assessment reports will include the following:

- Background – description of the site assessment or waste mangement area being addressed including relevant history; relevant geographical information.
- Exposure scenarios - description of receptor groups and pathways for which risks will be characterized.
- Data evaluation – description of data sources selected for use in the risk assessment; details of data treatment.
- Exposure assessment – presentation of exposure parameters and media-specific EPCs; presentation of methodology for calculating exposures; resulting exposures.
- Toxicity assessment – presentation of noncarcinogenic and carcinogenic toxicity criteria; discussion of human health effects associated with risk-driving COPCs.
- Risk characterization – presentation of methodologies for characterizing risks; calculated noncarcinogenic and carcinogenic risks.
- Uncertainties – qualitative and quantitative assessments of key uncertainties and data gaps; a description of the impacts of uncertainties on resulting risk estimates.
- Conclusions.
- References.

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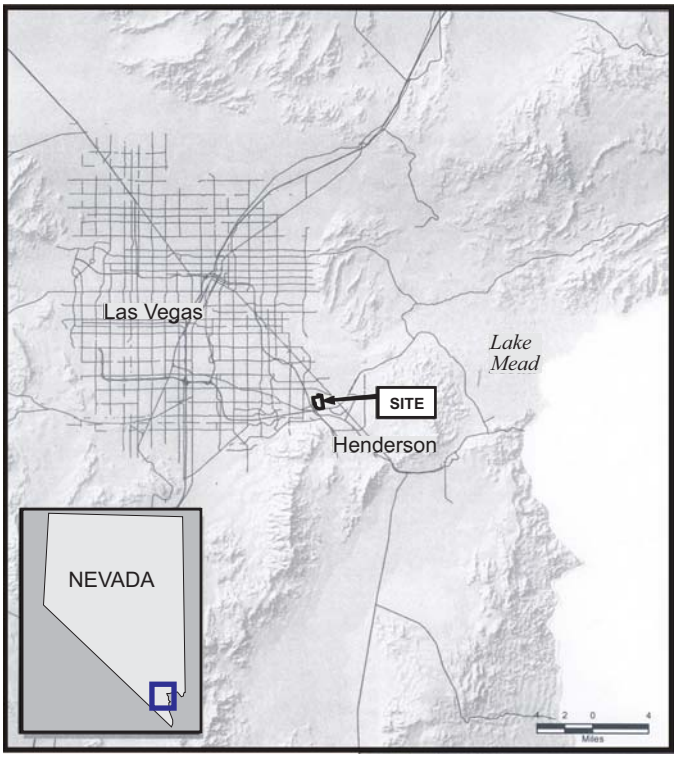
FIGURES



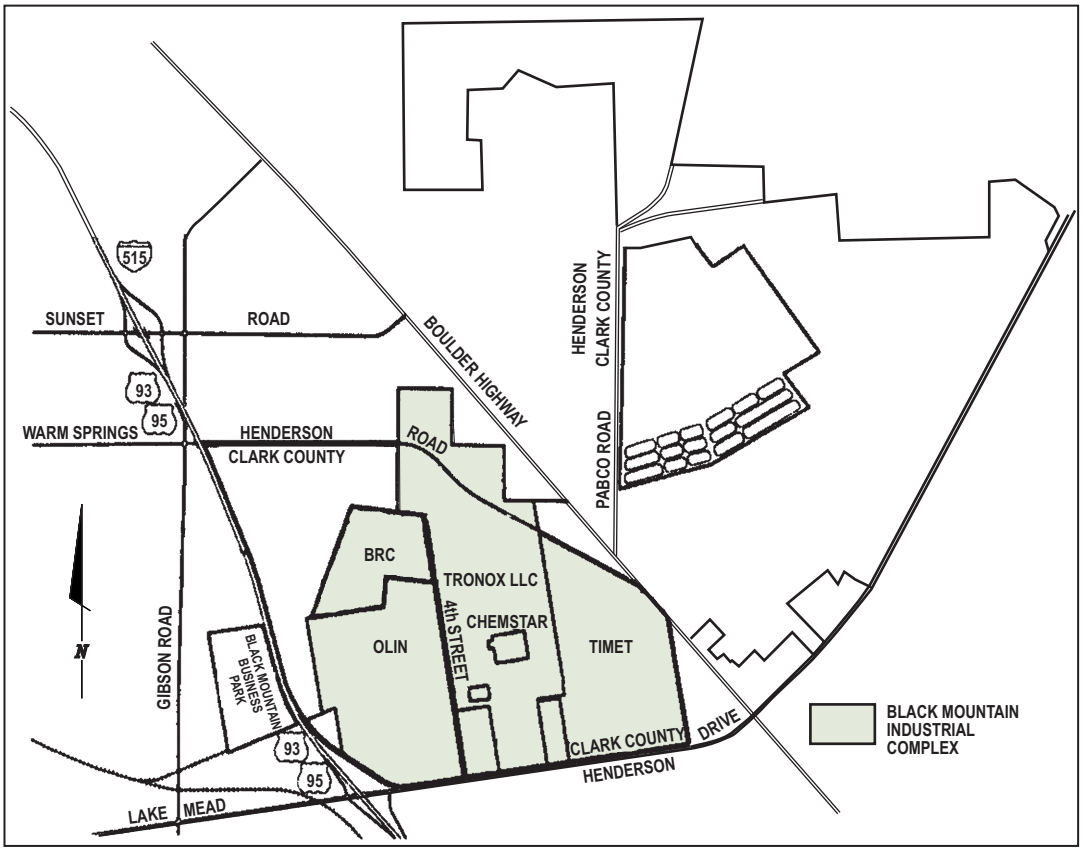


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Figure 1-1.
Site Location Map

Risk Assessment Work Plan
Former Stauffer Chemical Company Facility
Henderson, Nevada

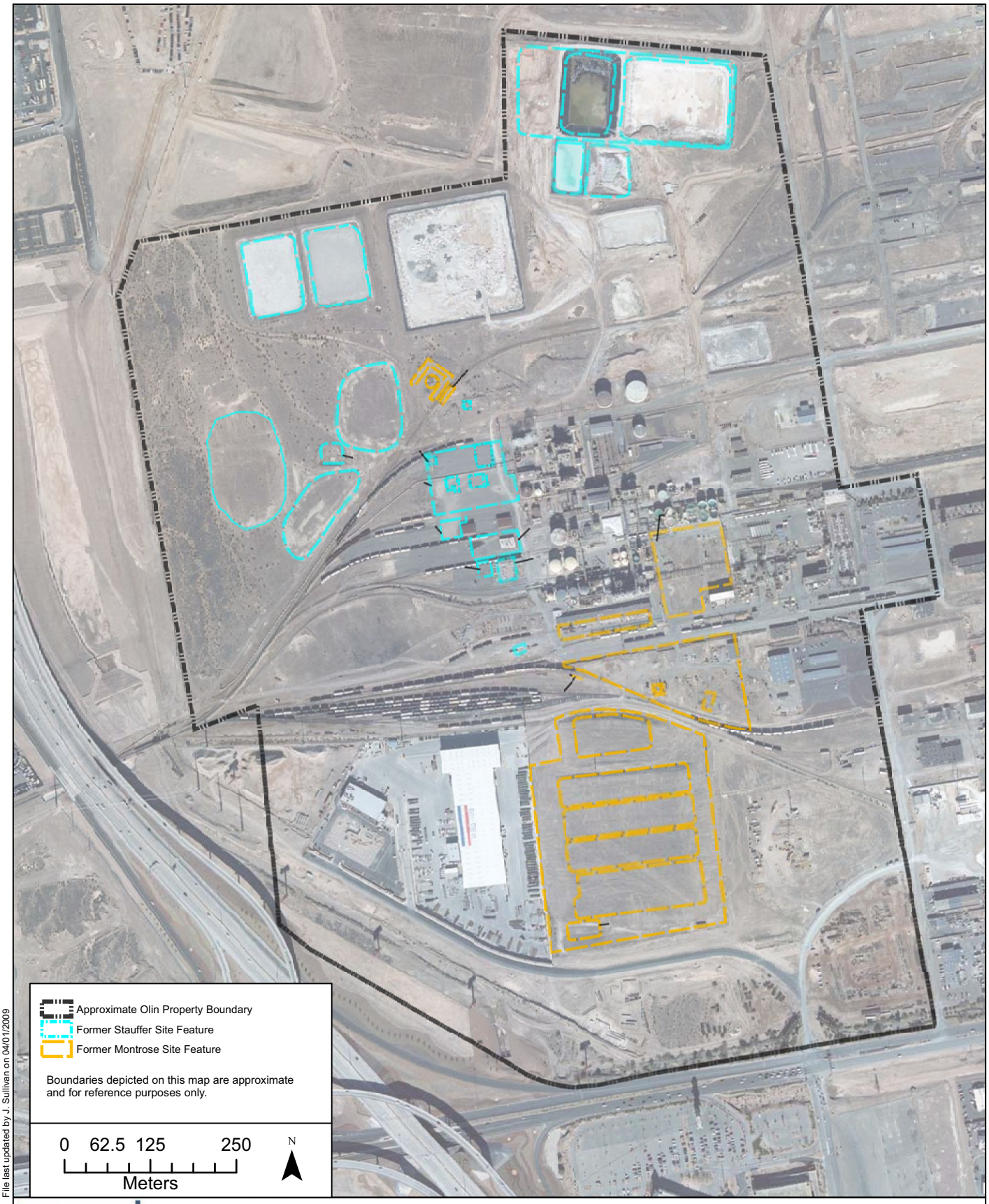

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Figure 1-2.
Former Montrose and Stauffer Site.
Henderson, NV.

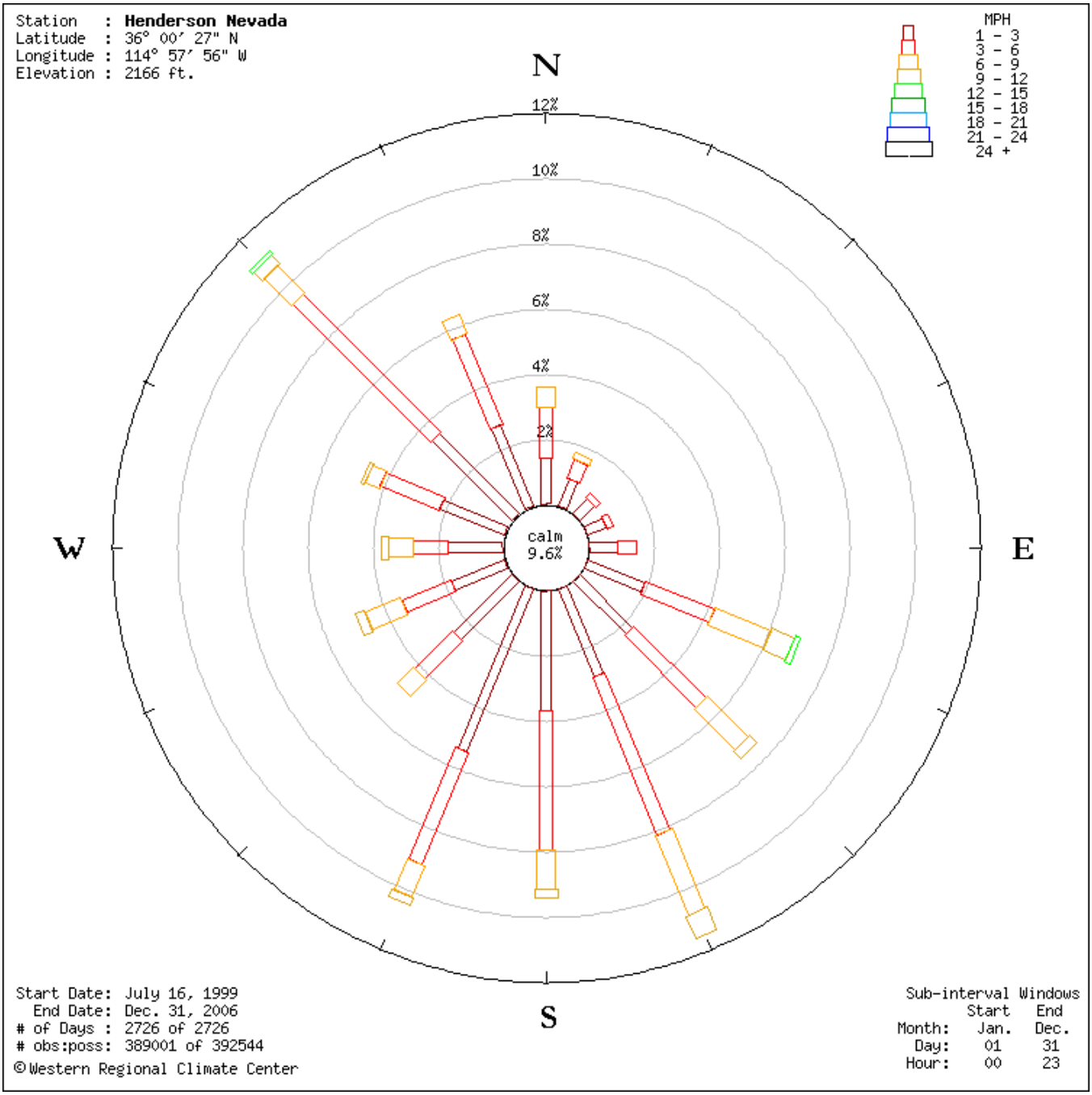
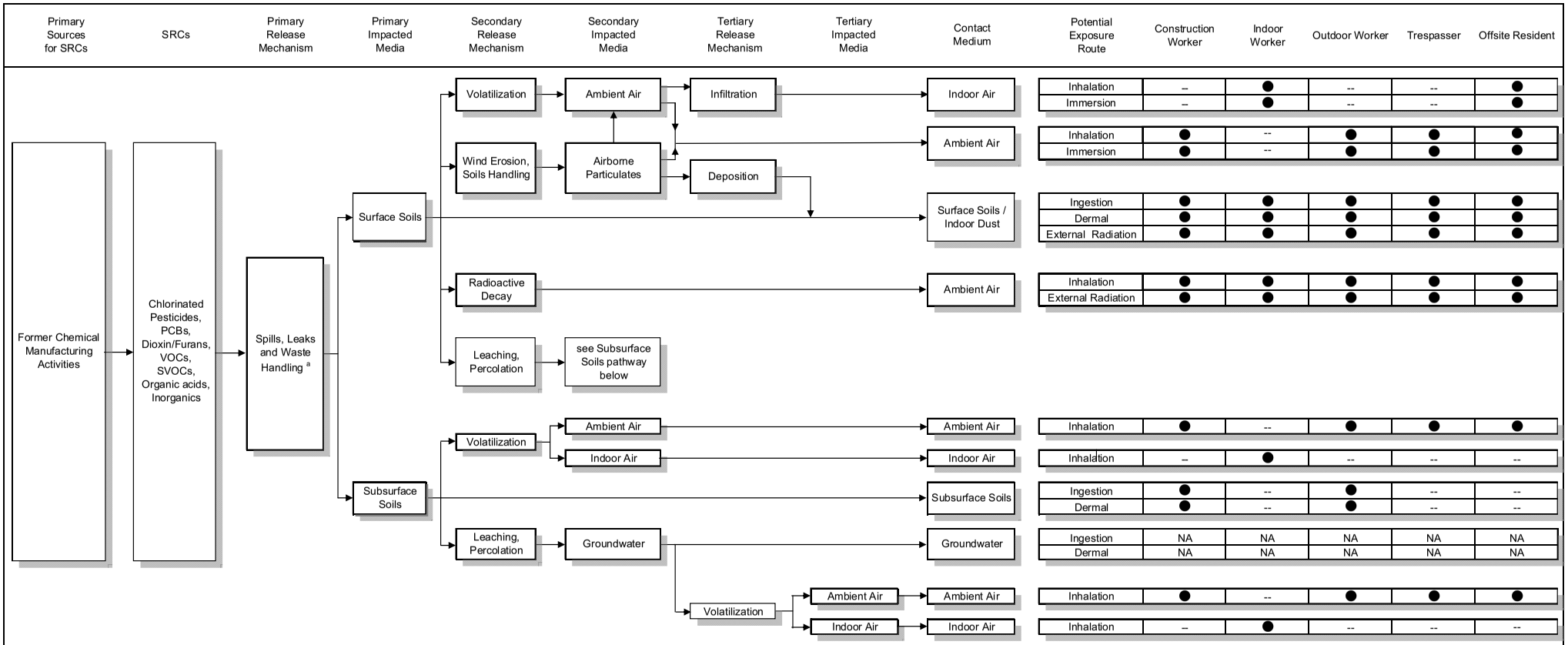


Figure 1-3.
Windrose for Henderson, Nevada

Risk Assessment Work Plan
Former Stauffer Chemical Company Facility
Henderson Nevada



Notes:
SRC = site-related chemical
● = complete exposure pathway
-- = incomplete exposure pathway
→ = complete pathway
NA = Not Applicable. Groundwater will not be evaluated for consumptive use in the risk assessment.
[a] Waste handling includes routine aqueous discharge to effluent and wastewater management systems (process and storm sewers, ponds and associated waste lines, leach field and ditches).

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Figure 2-1.
CSM and Human Exposure Pathways

Risk Assessment Work Plan
Former Stauffer Chemical Company
Henderson, Nevada

TABLES

Table 5-1. Toxic Equivalency Factors and Relative Potency Factors.

Dioxin/Furan Congener	TEF[a]
PCDDs	
2,3,7,8-TCDD	1
1,2,3,7,8-PeCDD	1
1,2,3,4,7,8-HxCDD	0.1
1,2,3,6,7,8-HxCDD	0.1
1,2,3,7,8,9-HxCDD	0.1
1,2,3,4,6,7,8-HpCDD	0.01
OCDD	0.0001
PCDFs	
2,3,7,8-TCDF	0.1
1,2,3,7,8-PeCDF	0.05
2,3,4,7,8-PeCDF	0.5
1,2,3,4,7,8-HxCDF	0.1
1,2,3,6,7,8-HxCDF	0.1
1,2,3,7,8,9-HxCDF	0.1
2,3,4,6,7,8-HxCDF	0.1
1,2,3,4,6,7,8-HpCDF	0.01
1,2,3,4,7,8,9-HpCDF	0.01
OCDF	0.0001
Non-Ortho PCBs	
PCB 77	0.0001
PCB 81	0.0001
PCB 126	0.1
PCB 169	0.01
Mono-Ortho PCBs	
PCB 105	0.0001
PCB 114	0.0005
PCB 118	0.0001
PCB 123	0.0001
PCB 156	0.0005
PCB 157	0.0005
PCB 167	0.00001
PCB 189	0.0001
PAHs	**RPF[b]**
Benzo(a)pyrene	1.0
Benzo(a)anthracene	0.1
Benzo(b)fluoranthene	0.1
Benzo(k)fluoranthene	0.01
Dibenzo(a,h)anthracene	1
Indeno(1,2,3-cd)pyrene	0.1
Chrysene	0.001

Notes:
[a] Source: Van den Berg et al. (1998).
[b] Source: USEPA (1993).

APPENDIX A

SITE-RELATED CHEMICALS LIST AS DETAILED IN HARGIS + ASSOCIATES, INC. (2008)

Table A-1. Site-Related Chemical List.

Group	Chemical	CAS Number	Montrose SRC [a]	SMC SRC [b]	Water	Soil
ALDEHYDES	Acetaldehyde	75-07-0	✓		Y	Y
ALDEHYDES	Chloral	75-87-6	✓			
ALDEHYDES	Chloral Hydrate	302-17-0	✓		Y	Y
ALDEHYDES	Chloroacetaldehyde	107-20-0	✓		Y	Y
ALDEHYDES	Dichloroacetaldehyde	79-02-7	✓			
ALDEHYDES	Formaldehyde	50-00-0		✓	Y	Y
ASBESTOS	Asbestos	1332-21-4		✓		
CHEMICALS UNDER REVIEW	Total Petroleum Hydrocarbons	NA		✓	Y	Y
DIOXINS/FURANS	1,2,3,4,6,7,8,9-Octachlorodibenzofuran	39001-02-0		✓	Y	Y
DIOXINS/FURANS	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	3268-87-9		✓	Y	Y
DIOXINS/FURANS	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	35822-46-9		✓	Y	Y
DIOXINS/FURANS	1,2,3,4,6,7,8-Heptachlorodibenzofuran	67562-39-4		✓	Y	Y
DIOXINS/FURANS	1,2,3,4,7,8,9-Heptachlorodibenzofuran	55673-89-7		✓	Y	Y
DIOXINS/FURANS	1,2,3,4,7,8-Hexachlorodibenzofuran	70648-26-9		✓	Y	Y
DIOXINS/FURANS	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	39227-28-6		✓	Y	Y
DIOXINS/FURANS	1,2,3,6,7,8-Hexachlorodibenzofuran	57117-44-9		✓	Y	Y
DIOXINS/FURANS	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	57653-85-7		✓	Y	Y
DIOXINS/FURANS	1,2,3,7,8,9-Hexachlorodibenzofuran	72918-21-9		✓	Y	Y
DIOXINS/FURANS	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	19408-74-3		✓	Y	Y
DIOXINS/FURANS	1,2,3,7,8-Pentachlorodibenzofuran	57117-41-6		✓	Y	Y
DIOXINS/FURANS	1,2,3,7,8-Pentachlorodibenzo-p-dioxin	40321-76-4		✓	Y	Y
DIOXINS/FURANS	2,3,4,6,7,8-Hexachlorodibenzofuran	60851-34-5		✓	Y	Y
DIOXINS/FURANS	2,3,4,7,8-Pentachlorodibenzofuran	57117-31-4		✓	Y	Y
DIOXINS/FURANS	2,3,7,8-Tetrachlorodibenzofuran	51207-31-9		✓	Y	Y
DIOXINS/FURANS	2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746-01-6		✓	Y	Y
GENERAL CHEMICAL	Total Dissolved Solids	NA	✓	✓	Y	Y
INDICATOR CHEMICAL	Alkalinity as CaCO3 [Sodium Hydroxide]	NA	✓		Y	Y
INDICATOR CHEMICAL	Ammonia-N2	7664-41-7	✓	✓	Y	Y
INDICATOR CHEMICAL	Chloride	16887-00-6	✓		Y	Y
INDICATOR CHEMICAL	Iron (Total)	7439-89-6	✓	✓	Y	Y
INDICATOR CHEMICAL	pH (in Soil)	NA	✓		Y	Y
INDICATOR CHEMICAL	pH (in Water)	NA	✓		Y	Y
INDICATOR CHEMICAL	Sodium	7440-23-5	✓	✓	Y	Y
INDICATOR CHEMICAL	Sulfate	14808-79-8	✓		Y	Y
INDICATOR CHEMICAL	Sulfur - total	63705-05-5	✓			
INDICATOR CHEMICAL	Total Phosphorus	7723-14-0	✓	✓	Y	Y
INORGANIC	Ammonium Chloride	12125-02-9	✓		Y	Y
INORGANIC	Bicarbonate	71-52-3		✓	Y	Y
INORGANIC	Calcium carbonate	471-34-1		✓	Y	Y
INORGANIC	Calcium hydroxides	1305-62-0		✓	Y	Y
INORGANIC	Chloride	16887-00-6	✓		Y	Y
INORGANIC	Chlorine	7782-50-5	✓	✓	Y	Y
INORGANIC	Cyanide	57-12-5	✓	✓	Y	Y
INORGANIC	Ferric Chloride	7705-08-0	✓		Y	Y
INORGANIC	Fluoride	16984-48-8	✓		Y	Y
INORGANIC	Graphite	7782-42-5		✓	Y	Y
INORGANIC	Hydrochloric Acid	7647-01-0	✓	✓	Y	Y
INORGANIC	Iodine	7553-56-2		✓	Y	Y
INORGANIC	Iodine chloride	7790-99-0		✓	Y	Y
INORGANIC	Magnesium hydroxide	1309-42-8		✓	Y	Y
INORGANIC	Magnesium oxide	1309-48-4		✓	Y	Y
INORGANIC	Nitrate	14797-55-8		✓	Y	Y
INORGANIC	Nitrogen Chloride	10025-85-1	✓	✓		
INORGANIC	Phosphoric Acid	7664-38-2	✓	✓	Y	Y
INORGANIC	Phosphorus pentasulfide	1314-80-3		✓	Y	Y
INORGANIC	Phosphorus Trichloride	7719-12-2	✓		Y	Y
INORGANIC	Sodium carbonate	497-19-8		✓	Y	Y
INORGANIC	Sodium chlorate	7775-09-9		✓	Y	Y
INORGANIC	Sodium chloride	7647-14-5		✓	Y	Y
INORGANIC	Sodium Hydroxide	1310-73-2	✓	✓	Y	Y
INORGANIC	Sodium Hypochlorite	7681-52-9	✓	✓	Y	Y
INORGANIC	Sodium salt of Diethyl phosphorodithioic acid	3338-24-7		✓		

Table A-1. Site-Related Chemical List.

Group	Chemical	CAS Number	Montrose SRC [a]	SMC SRC [b]	Water	Soil
INORGANIC	Sodium salt of Dimethyl phosphorodithioic acid	26377-29-7		✓		
INORGANIC	Sodium sulfate	7757-82-6		✓	Y	Y
INORGANIC	Sulfate	14808-79-8	✓		Y	Y
INORGANIC	Sulfuric Acid	7664-93-9	✓	✓	Y	Y
INORGANIC	Total Dissolved Solids	TDS		✓	Y	Y
INORGANIC	White phosphorus	12185-10-3		✓	Y	Y
METAL	Aluminum	7429-90-5	✓	✓	Y	Y
METAL	Antimony	7440-36-0	✓	✓	Y	Y
METAL	Arsenic	7440-38-2	✓	✓	Y	Y
METAL	Barium	7440-39-3	✓		Y	Y
METAL	Beryllium	7440-41-7	✓	✓	Y	Y
METAL	Cadmium	7440-43-9	✓	✓	Y	Y
METAL	Calcium	7440-70-2	✓	✓	Y	Y
METAL	Chromium (Total)	7440-47-3	✓	✓	Y	Y
METAL	Chromium VI (in Soil)	18540-29-9	✓	✓	Y	Y
METAL	Chromium VI (in Water)	18540-29-9	✓	✓	Y	Y
METAL	Cobalt	7440-48-4	✓	✓	Y	Y
METAL	Copper	7440-50-8	✓	✓	Y	Y
METAL	Iron (Total)	7439-89-6	✓	✓	Y	Y
METAL	Lead	7439-92-1	✓	✓	Y	Y
METAL	Magnesium	7439-95-4	✓	✓	Y	Y
METAL	Manganese	7439-96-5	✓	✓	Y	Y
METAL	Mercury [Mercury (in Soil)]	7439-97-6	✓	✓	Y	Y
METAL	Mercury [Mercury (in Water)]	7439-97-6	✓	✓	Y	Y
METAL	Molybdenum	7439-98-7	✓		Y	Y
METAL	Nickel	7440-02-0	✓	✓	Y	Y
METAL	Phosphorus	7723-14-0	✓	✓	Y	Y
METAL	Phosphorus, white	7723-14-0	✓	✓	Y	Y
METAL	Potassium	7440-09-7	✓	✓	Y	Y
METAL	Selenium	7782-49-2	✓	✓	Y	Y
METAL	Silver	7440-22-4	✓	✓	Y	Y
METAL	Sodium	7440-23-5	✓	✓	Y	Y
METAL	Sulfur, molecular	7704-34-9	✓		Y	Y
METAL	Thallium	7440-28-0	✓	✓	Y	Y
METAL	Tin	7440-31-5	✓	✓	Y	Y
METAL	Titanium	7440-32-6		✓	Y	Y
METAL	Vanadium	7440-62-2	✓	✓	Y	Y
METAL	Zinc	7440-66-6	✓	✓	Y	Y
ORGANIC ACIDS	4-Chlorobenzene Sulfonic Acid (pCBSA)	98-66-8	✓	✓		
ORGANIC ACIDS	Benzenesulfonic acid	98-11-3		✓		
ORGANIC ACIDS	Diethyl phosphorodithioic acid	298-06-6		✓		
ORGANIC ACIDS	Dimethyl phosphorodithioic acid	756-80-9		✓		
ORGANIC ACIDS	Phthalic acid	88-99-3		✓		
PCB	2,2'-Dichlorobiphenyl	13029-08-8	✓		Y	
PCB	2,3'-Dichlorobiphenyl	25569-80-6	✓		Y	
PCB	2,3-Dichlorobiphenyl	16605-91-7	✓		Y	
PCB	2,4'-Dichlorobiphenyl	34883-43-7	✓		Y	
PCB	2,4-Dichlorobiphenyl	33284-50-3	✓		Y	
PCB	2,5-Dichlorobiphenyl	34883-39-1	✓		Y	
PCB	2,6-Dichlorobiphenyl	33146-45-1	✓		Y	
PCB	3,3'-Dichlorobiphenyl	2050-67-1	✓		Y	
PCB	3,4'-Dichlorobiphenyl	2974-90-5	✓		Y	
PCB	3,4-Dichlorobiphenyl	2974-92-7	✓		Y	
PCB	3,5-Dichlorobiphenyl	34883-41-5	✓		Y	
PCB	4,4'-Dichlorobiphenyl	2050-68-2	✓		Y	
PCB	Aroclor 1016	12674-11-2	✓	✓	Y	Y
PCB	Aroclor 1221	11104-28-2	✓	✓	Y	Y
PCB	Aroclor 1232	11141-16-5	✓	✓	Y	Y
PCB	Aroclor 1242	53469-21-9	✓	✓	Y	Y
PCB	Aroclor 1248	12672-29-6	✓	✓	Y	Y
PCB	Aroclor 1254	11097-69-1	✓	✓	Y	Y
PCB	Aroclor 1260	11096-82-5	✓	✓	Y	Y

Table A-1. Site-Related Chemical List.

Group	Chemical	CAS Number	Montrose SRC [a]	SMC SRC [b]	Water	Soil
PCB	PCB 077	32598-13-3	✓	✓	Y	
PCB	PCB 081	70362-50-4	✓	✓	Y	
PCB	PCB 105	32598-14-4	✓	✓	Y	
PCB	PCB 114	74472-37-0	✓	✓	Y	
PCB	PCB 118	31508-00-6	✓	✓	Y	
PCB	PCB 123	65510-44-3	✓	✓	Y	
PCB	PCB 126	57465-28-8	✓	✓	Y	
PCB	PCB 156	38380-08-4	✓	✓	Y	
PCB	PCB 157	69782-90-7	✓	✓	Y	
PCB	PCB 167	52663-72-6	✓	✓	Y	
PCB	PCB 169	32774-16-6	✓	✓	Y	
PCB	PCB 189	39635-31-9	✓	✓	Y	
PESTICIDE	2,4' -DDD	53-19-0	✓	✓		
PESTICIDE	2,4' -DDE	3424-82-6	✓	✓		
PESTICIDE	2,4' -DDT	789-02-6	✓			
PESTICIDE	4,4' -DDD	72-54-8	✓	✓	Y	Y
PESTICIDE	4,4' -DDE	72-55-9	✓	✓	Y	Y
PESTICIDE	4,4' -DDT	50-29-3	✓	✓	Y	Y
PESTICIDE	A-BHC	319-84-6	✓	✓	Y	Y
PESTICIDE	Aldrin	309-00-2	✓	✓	Y	Y
PESTICIDE	B-BHC	319-85-7	✓	✓	Y	Y
PESTICIDE	Carbophenothion	786-19-6		✓		
PESTICIDE	D-BHC	319-86-8	✓	✓	Y	Y
PESTICIDE	Dieldrin	60-57-1	✓	✓	Y	Y
PESTICIDE	Endosulfan I	959-98-8	✓	✓	Y	Y
PESTICIDE	Endosulfan Sulfate	1031-07-8	✓	✓	Y	Y
PESTICIDE	Endrin	72-20-8	✓	✓	Y	Y
PESTICIDE	Endrin Aldehyde	7421-93-4	✓	✓	Y	Y
PESTICIDE	G-BHC	58-89-9	✓	✓	Y	Y
PESTICIDE	Heptachlor Epoxide	1024-57-3	✓	✓	Y	Y
PESTICIDE	Methyl-carbophenothion	953-17-3		✓		
PESTICIDE	Phosmet	732-11-6		✓		
SVOC	1-(4-chlorophenyl)-1-propanone	6285-05-8	✓			
SVOC	1,1'-Sulfonybis benzene	127-63-9		✓		
SVOC	1,2,3,4-Tetrachlorobenzene	634-66-2	✓	✓		
SVOC	1,2,4,5-Tetrachlorobenzene	95-94-3	✓	✓		
SVOC	1,2-Diphenyl hydrazine	122-66-7	✓			
SVOC	1-chloro-4-(methylsulfonyl) benzene	98-57-7		✓		
SVOC	2,2'-Dichlorobenzil	21854-95-5	✓		Y	Y
SVOC	2,4,5-Trichlorophenol	95-95-4	✓	✓	Y	Y
SVOC	2,4,6-Trichlorophenol	88-06-2	✓	✓		
SVOC	2,4-Dichlorophenol	120-83-2	✓	✓	Y	Y
SVOC	2,4-Dimethylphenol	105-67-9		✓	Y	Y
SVOC	2-Chlorophenol	95-57-8	✓	✓	Y	Y
SVOC	4,4'-Dichlorobenzil	3457-46-3	✓			
SVOC	4-Chloro-3-methylphenol	35421-08-0	✓		Y	Y
SVOC	4-Chlorophenyl methyl sulfide	123-09-1		✓	Y	Y
SVOC	4-Nitrophenol	100-02-7	✓			
SVOC	Benzo(a)anthracene	56-55-3		✓		
SVOC	Benzo(a)pyrene	50-32-8	✓	✓		
SVOC	Benzo(b)fluoranthene	205-99-2		✓	Y	Y
SVOC	Benzo(g,h,i)perylene	191-24-2		✓	Y	Y
SVOC	Benzo(k)fluoranthene	207-08-9		✓	Y	Y
SVOC	Benzoic Acid	65-85-0	✓	✓		
SVOC	Benzophenone	119-61-9		✓		
SVOC	Bis(2-ethylhexyl)phthalate	117-81-7	✓	✓		
SVOC	Bis-(chloromethyl)ether	542-88-1		✓	Y	Y
SVOC	Bis(p-chlorophenyl)disulfide	1142-19-4		✓		
SVOC	Chlorobenzenethiol	106-54-7		✓		
SVOC	Chrysene	218-01-9	✓	✓	Y	Y
SVOC	Dibenzo(a,h)anthracene	53-70-3		✓	Y	Y
SVOC	Diethyl phthalate	84-66-2		✓	Y	Y

Table A-1. Site-Related Chemical List.

Group	Chemical	CAS Number	Montrose SRC [a]	SMC SRC [b]	Water	Soil
SVOC	Di-n-butyl phthalate	84-74-2	✓	✓	Y	Y
SVOC	Di-n-octyl phthalate	117-84-0		✓		
SVOC	Fluoranthene	206-44-0	✓	✓	Y	Y
SVOC	Hexachlorobenzene	118-74-1	✓	✓	Y	Y
SVOC	Hexachloroethane	67-72-1		✓	Y	Y
SVOC	Indeno(1,2,3-cd)pyrene	193-39-5		✓		
SVOC	N-Hydroxymethylphthalimide	118-29-6		✓		
SVOC	Octachlorostyrene	29082-74-4	✓	✓		
SVOC	p-Chlorophenyl sulfone	80-07-9		✓		
SVOC	Pentachlorobenzene	608-93-5	✓	✓		
SVOC	Pentachlorophenol	87-86-5	✓		Y	Y
SVOC	Phenanthrene	85-01-8		✓	Y	Y
SVOC	Phenol (Total)	108-95-2	✓	✓	Y	Y
SVOC	Phenyl disulfide	882-33-7		✓		
SVOC	Phenyl sulfide	139-66-2		✓		
SVOC	Pyrene	129-00-0	✓	✓	Y	Y
SVOC	Pyridine	110-86-1		✓	Y	Y
SVOC	Thiophenol	108-98-5		✓		
TIC	1,1'-Thiobis [4-Chloro]Benzene	5181-10-2		✓		
TIC	1,2,3,5-Tetrachlorobenzene	634-90-2	✓	✓		
TIC	1,2,3-Trimethylbenzene	526-73-8		✓		
TIC	1,2,4-Trithiolane	289-16-7		✓		
TIC	1,5-Dichloroanthracene	6406-96-8	✓			
TIC	1,8-Dichloroanthracene	14381-66-9	✓			
TIC	1-Nitropropane	108-03-2	✓			
TIC	2,2,2-Trichloroethanol	115-20-8	✓			
TIC	2,3-Dichloroanthracene	613-07-0	✓			
TIC	2,3-Dichlorostyrene	213-28-6	✓			
TIC	2,4-Dichlorostyrene	21-27-5	✓			
TIC	2,5-Dichlorostyrene	1123-84-8	✓			
TIC	2,6-dichlorostyrene	28469-92-3	✓			
TIC	2-Chloro benzenethiol	6320-03-2		✓		
TIC	2-Chlorobenzyl chloride	611-19-8	✓			
TIC	2-Nitropropane	79-46-9	✓			
TIC	3,4-dichlorostyrene	2039-83-0	✓			
TIC	3,5-Heptanedione, 2,6-Dimethyl	18362-64-6		✓		
TIC	3-Chloro-Benzenethiol	2037-31-2		✓		
TIC	3-Chlorobenzyl chloride	620-20-2	✓			
TIC	3-Hexene-2,5-Dione (cis and trans)	4436-75-3		✓		
TIC	4-Chloro benzoylchloride	122-01-0		✓		
TIC	4-Chlorobenzaldehyde	104-88-1		✓		
TIC	4-Chloro-benzoic Acid	26264-09-5		✓		
TIC	4-Chlorobenzyl chloride	104-83-6	✓			
TIC	9,10-Dichloroanthracene	605-48-1	✓			
TIC	Alkane	NA	✓			
TIC	Alkyl Alkane	NA	✓			
TIC	Benzenesulfinothioic acid, phenylester	1208-20-4		✓		
TIC	bis-(2-chlorophenylmethanone)	NA	✓			
TIC	bis-(3-chlorophenylmethanone)	NA	✓			
TIC	bis-(4-chlorophenylmethanone)	90-98-2	✓	✓		
TIC	Chloroalkylbenzene	NA	✓			
TIC	Chloro-iodo-Benzene	615-41-8		✓		
TIC	Chloromethyl phthalimide	17564-64-6		✓		
TIC	Cyclododecene (CDEN)	1501-82-2	✓			
TIC	Ethyl Ether	60-29-7	✓			
TIC	Heptachlorostyrene	61255-81-0	✓			
TIC	Hexachlorostyrene	61128-00-5	✓			
TIC	Isoheptane	31394-54-4		✓		
TIC	Methanone, (3-Chlorophenyl)(4-Chlorophenyl)	7498-66-0		✓		
TIC	Methylsulfinyl benzene	1193-82-4		✓		
TIC	Methylthio-Benzene	100-68-5		✓		
TIC	O,O,A-Trimethlylester phosphorodithioic acid	2953-29-9		✓		

Table A-1. Site-Related Chemical List.

Group	Chemical	CAS Number	Montrose SRC [a]	SMC SRC [b]	Water	Soil
TIC	Octasulfur	10544-50-0		✓		
TIC	Paraformaldehyde	30525-89-4		✓		
TIC	Pentachlorocyclohexane	22138-39-2	✓			
TIC	Pentachlorostyrene	83484-75-7	✓			
TIC	Phthalimide	85-41-6		✓		
TIC	Polyethylene Glycol	25322-68-3	✓			
TIC	Sodium thiophenate	930-69-8		✓		
TIC	Sulfenone	80-00-2		✓		
TIC	Tetrachlorocyclohexane	129-00-0	✓	✓		
TIC	Tetrachlorostyrene	NA	✓			
TIC	Tetrachlorothiophene	6012-97-1		✓		
TIC	Trichlorostyrene	NA	✓			
TIC	Unknown	NA	✓			
TIC	Unknown Brominated Hydrocarbon	NA	✓			
TIC	Unknown Chlorinated Aromatics	NA	✓			
TIC	Unknown Chlorinated Benzene	NA	✓			
TIC	Unknown Chlorinated Compound	NA	✓			
TIC	Unknown Chlorinated Hydrocarbon	NA	✓			
TIC	Unknown Chlorinated Ketone	NA	✓			
TIC	Unknown Hydrocarbon	NA	✓			
TIC	Unknown Organic Acid	NA	✓			
VOC	1,1,1,2-Tetrachloroethane	630-20-6	✓		Y	Y
VOC	1,1,2,2-Tetrachloroethane	79-34-5	✓		Y	Y
VOC	1,1,2-Trichloroethane	79-00-5	✓		Y	Y
VOC	1,1-Dichloroethane	75-34-3	✓		Y	Y
VOC	1,1-Dichloroethene	75-35-4	✓		Y	Y
VOC	1,1-Dichloropropene	563-58-6	✓			
VOC	1,2,3-Trichlorobenzene	87-61-6	✓	✓	Y	Y
VOC	1,2,3-Trichloropropane	96-18-4	✓			
VOC	1,2,4-Trichlorobenzene	120-82-1	✓	✓		
VOC	1,2,4-Trimethylbenzene	95-63-6	✓	✓		
VOC	1,2-Dichlorobenzene	95-50-1	✓	✓	Y	Y
VOC	1,2-Dichloroethane	107-06-2	✓		Y	Y
VOC	1,3,5-Trichlorobenzene	108-70-3	✓	✓		
VOC	1,3,5-Trimethylbenzene	108-67-8	✓	✓		
VOC	1,3-Dichlorobenzene	541-73-1	✓	✓	Y	Y
VOC	1,3-Dichloropropane	142-28-9	✓			
VOC	1,4-Dichlorobenzene	106-46-7	✓	✓	Y	Y
VOC	1-Methylethylbenzene	98-82-8	✓		Y	Y
VOC	2,2,3-Trimethylbutane	464-06-2		✓		
VOC	2,2-Dimethylpentane	590-35-2		✓		
VOC	2,3-Dimethylpentane	565-59-3		✓		
VOC	2,4-Dimethylpentane	108-08-7		✓		
VOC	2-Butanone	78-93-3	✓		Y	Y
VOC	2-Chlorotoluene	95-49-8	✓			
VOC	2-Hexanone	591-78-6	✓		Y	Y
VOC	2-Methylhexane	591-76-4		✓		
VOC	3,3-Dimethylpentane	562-49-2		✓		
VOC	3-Chlorobenzoic Acid	535-80-8	✓			
VOC	3-Ethylpentane	617-78-7		✓		
VOC	3-Methylhexane	589-34-4		✓		
VOC	4-Chlorobenzoic Acid	74-11-3	✓			
VOC	4-Chlorotoluene	106-43-4	✓			
VOC	4-methyl-2-pentanone	108-10-1	✓		Y	Y
VOC	Acetone	67-64-1	✓	✓	Y	Y
VOC	Benzene	71-43-2	✓	✓	Y	Y
VOC	Bromobenzene	108-86-1	✓		Y	Y
VOC	Bromochloromethane	74-97-5	✓		Y	Y
VOC	Bromoform	75-25-2	✓		Y	Y
VOC	Carbon disulfide	75-15-0		✓		
VOC	Carbon Tetrachloride	56-23-5	✓	✓	Y	Y
VOC	Chlorobenzene	108-90-7	✓	✓	Y	Y
VOC	Chloroform	67-66-3	✓	✓	Y	Y

Table A-1. Site-Related Chemical List.

Group	Chemical	CAS Number	Montrose SRC [a]	SMC SRC [b]	Water	Soil
VOC	Chloromethane	74-87-3	✓		Y	Y
VOC	cis-1,2-Dichloroethene	156-59-2	✓		Y	Y
VOC	Dibromochloroethane	73506-94-2	✓			
VOC	Dibromochloromethane	124-48-1	✓		Y	Y
VOC	Dibromochloropropane (DBCP)	96-12-8	✓		Y	Y
VOC	Dichlorodifluoromethane	75-71-8	✓		Y	Y
VOC	Dimethyldisulfide	624-92-0		✓		
VOC	Ethyl Alcohol (Ethanol)	64-17-5	✓	✓		
VOC	Ethyl Chloride	75-00-3	✓		Y	Y
VOC	Ethylbenzene	100-41-4	✓		Y	Y
VOC	Hexachlorobutadiene	87-68-3	✓	✓	Y	Y
VOC	Isopropyl toluene	25155-15-1	✓			
VOC	m,p-Xylene	136777-61-2		✓	Y	Y
VOC	Methanol (Methyl alcohol)	67-56-1		✓		
VOC	Methylene Chloride	75-09-2	✓	✓	Y	Y
VOC	Naphthalene	91-20-3	✓	✓	Y	Y
VOC	n-Butyl benzene	104-51-8	✓			
VOC	n-Heptane	142-82-5		✓		
VOC	Nonanal	124-19-6		✓		
VOC	n-Propyl benzene	103-65-1	✓			
VOC	Rubber hydrocarbon solvent	64475-85-0	✓		Y	Y
VOC	sec-Butyl benzene	135-98-8	✓			
VOC	Styrene	100-42-5	✓			
VOC	tert-Butyl benzene	98-06-6	✓			
VOC	Tetrachloroethene (PCE)	127-18-4	✓		Y	Y
VOC	Toluene	108-88-3	✓	✓	Y	Y
VOC	trans-1,2-Dichloroethene	156-60-5	✓		Y	Y
VOC	trans-1,3-Dichloropropene	10061-02-6	✓		Y	Y
VOC	Trichloroethene (TCE)	79-01-6	✓		Y	Y
VOC	Trichlorofluoromethane	75-69-4	✓		Y	Y
VOC	Vinyl chloride	75-01-4	✓		Y	Y
VOC	Xylene (o)	1330-20-7	✓	✓	Y	Y
VOC	Xylenes (m,p)	1330-20-7	✓	✓	Y	Y

Source: Hargis. 2008. Conceptual site model, former Montrose and Stauffer facilities and downgradient areas to Las Vegas Wash, Henderson, Clark County, Nevada. Revision 1.0. DRAFT. Prepared for Montrose Chemical Corporation of California, Stauffer Management Company, LLC., Syngenta Crop Protection, Inc., and Pioneer Americas, LLC. Hargis + Associates, Inc.

Notes:
- CAS = chemical abstract service
- NA = not applicable, due to impractible analysis or certification does not exist
- PCB = polychlorinated biphenyl
- SRC = site-related chemical
- SMC = Stauffer Management Company
- SVOC = semi-volatile organic compound
- TEM = transmission electron microscope
- TIC = tentatively identified compound
- USEPA = U.S. Environmental Protection Agency
- VOC = volatile organic compound
- Y = yes
- ✓ = applicable

[a] List of Montrose SRCs approved by NDEP. 2006. Personal communication (letter to J. Kelly, Montrose Chemical Corporation of California, Bainbridge Island, WA, dated July 26, 2006, regarding regarding NDEP's approval of the Montrose SRC list). Nevada Division of Environmental Protection.

[b] List of Stauffer SRCs approved by NDEP. 2006. Personal communication (letter to G. Crouse, Syngenta Crop Protection, Inc., Greensboro, NC, L. Erickson, Stauffer Management Company, Golden, CO, and C. Sylvia, Pioneer Americas LLC, Henderson, NV, dated June 5, 2006, regarding NDEP's approval of the Stauffer SRC list). Nevada Division of Environmental Protection.

APPENDIX B

CHEMICALS TO BE EVALUATED FOR VAPOR INTRUSION POTENTIAL

Table B-1. EPA Evaluation of Toxicity and Volatility for Chemicals of Potential Concern for Vapor Intrusion.

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [a]	Is Chemical Sufficiently Volatile? [b]
83329	Acenaphthene	YES	YES
75070	Acetaldehyde	YES	YES
67641	Acetone	YES	YES
75058	Acetonitrile	YES	YES
98862	Acetophenone	YES	YES
107028	Acrolein	YES	YES
107131	Acrylonitrile	YES	YES
309002	Aldrin	YES	YES
319846	alpha-HCH (alpha-BHC)	YES	YES
62533	Aniline	YES	NO
120127	Anthracene	NO	YES
56553	Benz(a)anthracene	YES	NO
100527	Benzaldehyde	YES	YES
71432	Benzene	YES	YES
50328	Benzo(a)pyrene	YES	NO
205992	Benzo(b)fluoranthene	YES	YES
207089	Benzo(k)fluoranthene	NO	NO
65850	Benzoic Acid	NO	NO
100516	Benzyl alcohol	YES	NO
100447	Benzylchloride	YES	YES
91587	beta-Chloronaphthalene	YES	YES
319857	beta-HCH (beta-BHC)	YES	NO
92524	Biphenyl	YES	YES
111444	Bis(2-chloroethyl)ether	YES	YES
108601	Bis(2-chloroisopropyl)ether	YES	YES
117817	Bis(2-ethylhexyl)phthalate	NO	NO
542881	Bis(chloromethyl)ether	YES	YES
75274	Bromodichloromethane	YES	YES
75252	Bromoform	YES	YES
106990	1,3-Butadiene	YES	YES
71363	Butanol	YES	NO
85687	Butyl benzyl phthalate	NO	NO
86748	Carbazole	YES	NO
75150	Carbon disulfide	YES	YES
56235	Carbon tetrachloride	YES	YES
57749	Chlordane	YES	YES
126998	2-Chloro-1,3-butadiene (chloroprene)	YES	YES
108907	Chlorobenzene	YES	YES
109693	1-Chlorobutane	YES	YES
124481	Chlorodibromomethane	YES	YES
75456	Chlorodifluoromethane	YES	YES
75003	Chloroethane (ethyl chloride)	YES	YES
67663	Chloroform	YES	YES
95578	2-Chlorophenol	YES	YES
75296	2-Chloropropane	YES	YES
218019	Chrysene	YES	YES
156592	cis-1,2-Dichloroethylene	YES	YES
123739	Crotonaldehyde (2-butenal)	YES	YES
98828	Cumene	YES	YES
72548	DDD	YES	NO
72559	DDE	YES	YES

Table B-1. EPA Evaluation of Toxicity and Volatility for Chemicals of Potential Concern for Vapor Intrusion.

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [a]	Is Chemical Sufficiently Volatile? [b]
50293	DDT	YES	NO
53703	Dibenz(a,h)anthracene	YES	NO
132649	Dibenzofuran	YES	YES
96128	1,2-Dibromo-3-chloropropane	YES	YES
106934	1,2-Dibromoethane (ethylene dibromide)	YES	YES
541731	1,3-Dichlorobenzene	YES	YES
95501	1,2-Dichlorobenzene	YES	YES
106467	1,4-Dichlorobenzene	YES	YES
91941	3,3-Dichlorobenzidine	YES	NO
75718	Dichlorodifluoromethane	YES	YES
75343	1,1-Dichloroethane	YES	YES
107062	1,2-Dichloroethane	YES	YES
75354	1,1-Dichloroethylene	YES	YES
120832	2,4-Dichlorophenol	YES	NO
78875	1,2-Dichloropropane	YES	YES
542756	1,3-Dichloropropene	YES	YES
60571	Dieldrin	YES	YES
84662	Diethylphthalate	YES	NO
105679	2,4-Dimethylphenol	YES	NO
131113	Dimethylphthalate	NO	NO
84742	Di-n-butyl phthalate	NO	NO
534521	4,6-Dinitro-2-methylphenol (4,6-dinitro-o-cresol)	YES	NO
51285	2,4-Dinitrophenol	YES	NO
121142	2,4-Dinitrotoluene	YES	NO
606202	2,6-Dinitrotoluene	YES	NO
117840	Di-n-octyl phthalate	NO	YES
115297	Endosulfan	YES	YES
72208	Endrin	YES	NO
106898	Epichlorohydrin	YES	YES
60297	Ethyl ether	YES	YES
141786	Ethylacetate	YES	YES
100414	Ethylbenzene	YES	YES
75218	Ethylene oxide	YES	YES
97632	Ethylmethacrylate	YES	YES
206440	Fluoranthene	NO	YES
86737	Fluorene	YES	YES
110009	Furan	YES	YES
58899	gamma-HCH (Lindane)	YES	YES
76448	Heptachlor	YES	YES
1024573	Heptachlor epoxide	YES	NO
87683	Hexachloro-1,3-butadiene	YES	YES
118741	Hexachlorobenzene	YES	YES
77474	Hexachlorocyclopentadiene	YES	YES
67721	Hexachloroethane	YES	YES
110543	Hexane	YES	YES
74908	Hydrogen cyanide	YES	YES
193395	Indeno(1,2,3-cd)pyrene	NO	NO
78831	Isobutanol	YES	YES
78591	Isophorone	YES	NO
7439976	Mercury (elemental)	YES	YES
126987	Methacrylonitrile	YES	YES

Table B-1. EPA Evaluation of Toxicity and Volatility for Chemicals of Potential Concern for Vapor Intrusion.

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [a]	Is Chemical Sufficiently Volatile? [b]
72435	Methoxychlor	YES	YES
79209	Methyl acetate	YES	YES
96333	Methyl acrylate	YES	YES
74839	Methyl bromide	YES	YES
74873	Methyl chloride (chloromethane)	YES	YES
108872	Methylcyclohexane	YES	YES
74953	Methylene bromide	YES	YES
75092	Methylene chloride	YES	YES
78933	Methylethylketone (2-butanone)	YES	YES
108101	Methylisobutylketone	YES	YES
80626	Methylmethacrylate	YES	YES
91576	2-Methylnaphthalene	YES	YES
108394	3-Methylphenol (m-cresol)	YES	NO
95487	2-Methylphenol (o-cresol)	YES	NO
106455	4-Methylphenol (p-cresol)	YES	NO
99081	m-Nitrotoluene	YES	NO
1634044	MTBE	YES	YES
108383	m-Xylene	YES	YES
91203	Naphthalene	YES	YES
104518	n-Butylbenzene	YES	YES
98953	Nitrobenzene	YES	YES
100027	4-Nitrophenol	YES	NO
79469	2-Nitropropane	YES	YES
924163	N-Nitroso-di-n-butylamine	YES	YES
621647	N-Nitrosodi-n-propylamine	YES	NO
86306	N-Nitrosodiphenylamine	YES	NO
103651	n-Propylbenzene	YES	YES
88722	o-Nitrotoluene	YES	YES
95476	o-Xylene	YES	YES
106478	p-Chloroaniline	YES	NO
87865	Pentachlorophenol	YES	NO
108952	Phenol	YES	NO
99990	p-Nitrotoluene	YES	NO
106423	p-Xylene	YES	YES
129000	Pyrene	YES	YES
110861	Pyridine	YES	NO
135988	sec-Butylbenzene	YES	YES
100425	Styrene	YES	YES
98066	tert-Butylbenzene	YES	YES
630206	1,1,1,2-Tetrachloroethane	YES	YES
79345	1,1,2,2-Tetrachloroethane	YES	YES
127184	Tetrachloroethylene	YES	YES
108883	Toluene	YES	YES
8001352	Toxaphene	YES	NO
156605	trans-1,2-Dichloroethylene	YES	YES
76131	1,1,2-Trichloro-1,2,2-trifluoroethane	YES	YES
120821	1,2,4-Trichlorobenzene	YES	YES
79005	1,1,2-Trichloroethane	YES	YES
71556	1,1,1-Trichloroethane	YES	YES
79016	Trichloroethylene	YES	YES
75694	Trichlorofluoromethane	YES	YES

Table B-1. EPA Evaluation of Toxicity and Volatility for Chemicals of Potential Concern for Vapor Intrusion.

CAS No.	Chemical	Is Chemical Sufficiently Toxic? [a]	Is Chemical Sufficiently Volatile? [b]
95954	2,4,5-Trichlorophenol	YES	NO
88062	2,4,6-Trichlorophenol	YES	NO
96184	1,2,3-Trichloropropane	YES	YES
95636	1,2,4-Trimethylbenzene	YES	YES
108678	1,3,5-Trimethylbenzene	YES	YES
108054	Vinyl acetate	YES	YES
75014	Vinyl chloride (chloroethene)	YES	YES

Source: USEPA. 2002b. OSWER Draft guidance for evaluating the vapor intrusion to indoor air pathway from groundwater and soils (subsurface vapor intrusion guidance). EPA530-D-02-004. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC.

[a] A chemical is considered sufficiently toxic if the vapor concentration of the pure component poses an incremental lifetime cancer risk greater than 10^{-6} or a noncancer hazard index greater than 1.

[b] A chemical is considered sufficiently volatile if its Henry's Law Constant is $1x10^{-5}$ atm-m^3/mol or greater.

APPENDIX C

EXPOSURE EQUATIONS AND ASSUMPTIONS

EXHIBIT C-1. INCIDENTAL INGESTION OF CHEMICALS IN SOIL

$$LADD_{soil}, ADD_{soil} = \frac{C_{soil} \times IR_{soil} \times EF \times ED}{AT \times BW \times CF} \qquad \text{Eq. C-1}$$

where,

$LADD_{soil}$	=	lifetime average daily dose from incidental ingestion of soil (mg/kg-day)
ADD_{soil}	=	average daily dose from incidental ingestion of soil (mg/kg-day)
C_{soil}	=	concentration of chemical in soil (mg/kg)
IR_{soil}	=	soil ingestion rate (mg/day)
EF	=	exposure frequency for soil (days/year)
ED	=	exposure duration (years)
AT	=	averaging time (days)
BW	=	body weight (kg)
CF	=	unit conversion factor (mg/kg).

Parameter Values

Exposure Factor	Value		Units	Source
	CTE	RME		
Indoor Worker				
IR_{soil}	50	50	mg/day	USEPA (2002a), Exhibit 4-1
EF	250	250	days/year	USEPA (2002a), Exhibit 4-1
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002), Exhibit 4-1
AT_{nc}	2,555	9,125	days	ED x 365 days/year
AT_c	25,550	25,550	days	70 years x 365 days/year
BW	70	70	kg	USEPA (2002a), Exhibit 4-1
CF	1E+06	1E+06	mg/kg	Unit conversion factor
Outdoor Worker				
IR_{soil}	50	100	mg/day	USEPA (1991); USEPA (2002a), Exhibit 4-1
EF	225	225	days/year	USEPA (2002a), Exhibit 4-1
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a), Exhibit 4-1
AT_{nc}	2,555	9,125	days	ED x 365 days/year
AT_c	25,550	25,550	days	70 years x 365 days/year

Exposure Factor	Value		Units	Source
	CTE	RME		
BW	70	70	kg	USEPA (2002a), Exhibit 4-1
CF	1E+06	1E+06	mg/kg	Unit conversion factor
Construction Worker				
IR_{soil}	100	330	mg/day	BPJ; USEPA (2002a), Exhibit 5-1
EF	250	250	days/year	USEPA (2002a), Exhibit 5-1
ED	0.5	1	years	BPJ; USEPA (2002a), Exhibit 5-1
AT_{nc}	183	365	days	ED x 365 days/year
AT_c	25,550	25,550	days	70 years x 365 days/ year
BW	70	70	kg	USEPA (2002a), Exhibit 5-1
CF	1E+06	1E+06	mg/kg	Unit conversion factor
Trespasser				
IR_{soil}	50	100	mg/day	USEPA (1997a), Table 4-23; USEPA (1991)
EF	50	100	days/year	BPJ
ED	3	6	years	BPJ
AT_{nc}	1,095	2,190	days	ED x 365 days/year
AT_c	25,550	25,550	days	70 years x 365 days/ year
BW	60	60	kg	USEPA (1997a), Table 7-3 (Mean value for 13-19 year olds)
CF	1E+06	1E+06	mg/kg	Unit conversion factor

EXHIBIT C-2. DERMAL CONTACT WITH CHEMICALS IN SOIL

$$LDAD_{soil}, DAD_{soil} = \frac{DA_{event} \times SA \times EF \times ED \times EV}{AT \times BW} \qquad \text{Eq. C-2}$$

where,

$LDAD_{soil}$	=	lifetime dermal absorbed dose (mg/kg-day)
DAD_{soil}	=	dermal absorbed dose (mg/kg-day)
DA_{event}	=	absorbed dose per event (mg/cm^2)
SA	=	skin surface area available for contact (cm^2)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
EV	=	event frequency (day^{-1})
AT	=	averaging time (days)
BW	=	body weight (kg)

and,

$$DA_{event} = C_{soil} \times CF \times AF \times ABS_d \qquad \text{Eq. C-3}$$

where,

DA_{event}	=	absorbed dose per event (mg/cm^2)
C_{soil}	=	concentration of chemical in soil (mg/kg)
CF	=	unit conversion factor (kg/mg)
AF	=	adherence factor (mg/cm^2)
ABS_d	=	dermal absorption fraction, chemical-specific (unitless).

Parameter Values

Exposure Factor	Value		Units	Source
	CTE	RME		
Outdoor Worker				
AF	0.02	0.2	mg/cm^2	USEPA (2004a), Exhibit 3-5
ABS_d	chemical specific		unitless	--
SA	3,300	3,300	cm^2	USEPA (2004a), Exhibit 3-5 (Assumes short sleeved shirt, pants, and shoes are worn)
EF	225	225	days/year	USEPA (2002a), Exhibit 4-1
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a), Exhibit 4-1

Exposure Factor	Value		Units	Source
	CTE	RME		
EV	1	1	day^{-1}	USEPA (2004a), Exhibit 3-5
AT_{nc}	2,555	9,125	days	ED x 365 day/year
AT_c	25,550	25,550	days	70 years x 365 days/year
BW	70	70	kg	USEPA (2002a), Exhibit 4-1
CF	1E-06	1E-06	kg/mg	Unit conversion factor
Construction Worker				
AF	0.1	0.3	mg/cm^2	USEPA (2004a), Exhibit 3-3 (Study on construction workers)
ABS_d	Chemical specific		unitless	--
SA	3,300	3,300	cm^2	USEPA (2004a), Exhibit 3-5 (Assumes short sleeved shirt, pants, and shoes are worn)
EF	250	250	days/year	USEPA (2002a), Exhibit 5-1
ED	0.5	1	years	BPJ; USEPA (2002a), Exhibit 5-1
EV	1	1	day^{-1}	USEPA (2004a), Exhibit 3-5
AT_{nc}	183	365	days	ED x 365 day/year
AT_c	25,550	25,550	days	70 years x 365 days/year
BW	70	70	kg	USEPA (2002a), Exhibit 5-1
CF	1E-06	1E-06	kg/mg	Unit conversion factor
Trespasser				
AF	0.02	0.2	mg/cm^2	USEPA (2004a), Exhibit 3-5
ABS_d	Chemical specific		unitless	--
SA	5,300	5,300	cm^2	USEPA (2004a), Exhibit C-1 (Assumes short sleeved shirt, shorts, and shoes are worn, 13-18 year olds)
EF	50	100	days/year	BPJ
ED	3	6	years	BPJ
EV	1	1	day^{-1}	USEPA (2004a), Exhibit 3-5
AT_{nc}	1,095	2,190	days	ED x 365 day/year
AT_c	25,550	25,550	days	70 years x 365 days/year
BW	60	60	kg	USEPA (1997a), Table 7-3 (Mean value for 13-19 year olds)
CF	1E-06	1E-06	kg/mg	Unit conversion factor

EXHIBIT C-3. INHALATION OF INDOOR AND OUTDOOR AIR (CHEMICAL PARTICULATES AND VOLATILES)

$$EC = \frac{C_{air} \times ET \times EF \times ED}{AT} \qquad \text{Eq. C-4}$$

where,

EC	=	exposure concentration (μg/m^3)
C_{air}	=	chemical concentration (particulate or gas) in air (μg/m^3)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
AT	=	averaging time (hours).

Parameter Values

Exposure Factor	Value		Units	Source
	CTE	RME		
Indoor Worker				
ET	8	8	hours/day	Assumed as work day duration
EF	250	250	days/year	USEPA (2002a), Exhibit 4-1
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a); Exhibit 4-1
AT_{nc}	61,320	219,000	hours	ED x 365 day/year x 24 hours/day
AT_c	613,200	613,200	hours	70 years x 365 days/year x 24 hours/day
Outdoor Worker				
ET	8	8	hours/day	Assumed as work day duration
EF	225	225	days/year	USEPA (2002a), Exhibit 4-1
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a), Exhibit 4-1
AT_{nc}	61,320	219,000	hours	ED x 365 day/year x 24 hours/day
AT_c	613,200	613,200	hours	70 years x 365 days/year x 24 hours/day
Construction Worker				
ET	8	8	hours/day	Assumed as work day duration
EF	250	250	days/year	USEPA (2002a), Exhibit 5-1
ED	0.5	1	years	BPJ; USEPA (2002a), Exhibit 5-1
AT_{nc}	4,392	8,760	hours	ED x 365 day/year x 24 hours/day

Exposure Factor	Value		Units	Source
	CTE	RME		
AT_c	613,200	613,200	hours	70 years x 365 days/year x 24 hours/day
Trespasser				
ET	2	4	hours/day	BPJ
EF	50	100	days/year	BPJ
ED	3	6	years	BPJ
AT_{nc}	26,280	52,560	hours	ED x 365 days/year x 24 hours/day
AT_c	613,200	613,200	hours	70 years x 365 days/year x 24 hours/day
Resident, Adult				
ET[1]	16	16	hours/day	BPJ, (Assumes 8 hours away from home)
EF	350	350	days/year	USEPA (1991)
ED	7	24	years	USEPA (1991) (Represents adult portion) (Makes assumptions for CTE portion of time as adult and child as per NDEP (2008b))
AT_{nc}	61,320	210,240	hours	ED x 365 day/year x 24 hours/day
AT_c	613,200	613,200	hours	70 years x 365 days/year x 24 hours/day
Resident, Child				
ET[1]	16	16	hours/day	BPJ, (Assumes 8 hours away from home)
EF	350	350	days/year	USEPA (1991)
ED	2	6	years	USEPA (1991) (Represents child portion) (Makes assumptions for CTE portion of time as adult and child as per NDEP(2008b))
AT_{nc}	730	2,190	days	ED x 365 day/year
AT_c	613,200	613,200	hours	70 years x 365 days/year x 24 hours/day

[1] Evaluation may consider more than one microenvironment. Time-weighted ECs will incorporate information on ET and C_{air} in each microenvironment.

EXHIBIT C-4. INCIDENTAL INGESTION OF RADIONUCLIDES IN SOIL

$$Dose_{soil} = C_{soil} \times IR_{soil} \times EF \times ED \times CF \qquad \text{Eq. C5}$$

where,

$Dose_{soil}$	=	internal dose from incidental ingestion of soil (pCi)
C_{soil}	=	concentration of radionuclide in soil (pCi/g)
IR_{soil}	=	soil ingestion rate (mg/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
CF	=	unit conversion factor (g/mg).

Parameter Values

Exposure Factor	Value		Units	Source
	CTE	RME		
Indoor Worker				
IR_{soil}	50	50	mg/day	USEPA (2002a), Exhibit 4-1
EF	250	250	days/year	USEPA (2002a), Exhibit 4-1
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a); Exhibit 4-1
CF	1E-03	1E-03	g/mg	Unit conversion factor
Outdoor Worker				
IR_{soil}	50	100	mg/day	USEPA (1991); USEPA (2002a), Exhibit 4-1
EF	225	225	days/year	USEPA (2002a), Exhibit 4-1
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a); Exhibit 4-1
CF	1E-03	1E-03	g/mg	Unit conversion factor
Construction Worker				
IR_{soil}	100	330	mg/day	BPJ; USEPA (2002a), Exhibit 5-1
EF	250	250	days/year	USEPA (2002a), Exhibit 5-1
ED	0.5	1	years	BPJ; USEPA (2002a), Exhibit 5-1
CF	1E-03	1E-03	g/mg	Unit conversion factor
Trespasser				
IR_{soil}	50	100	mg/day	USEPA (1997a), Table 4-23; USEPA (1991)

Exposure Factor	Value		Units	Source
	CTE	RME		
EF	50	100	days/year	BPJ
ED	3	6	years	BPJ
CF	1E-03	1E-03	g/mg	Unit conversion factor

EXHIBIT C-5. INHALATION OF RADIONUCLIDES IN INDOOR AND OUTDOOR AIR (PARTICULATES) AND RADON

$$Dose_{inhal} = C_{air} \times InhR \times EF \times ED \qquad \text{Eq. C-6}$$

where,

$Dose_{inhal}$	=	internal dose from inhalation (pCi)
C_{air}	=	concentration of radionuclide in air (pCi/m^3)
InhR	=	inhalation rate (m^3/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years).

Parameter Values

Exposure Factor	Value		Units	Source
	CTE	RME		
Indoor Worker				
InhR	13	13	m^3/day	USEPA (1997a), Table 5-23 (Assumes moderate activity, 8 hours/day)
EF	250	250	days/year	USEPA (2002a), Exhibit 4-1
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a); Exhibit 4-1
Outdoor Worker				
InhR	20	20	m^3/day	USEPA (1997a), Table 5-23 (Assumes heavy activity, 8 hours/day)
EF	225	225	days/year	USEPA (2002a), Exhibit 4-1
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a); Exhibit 4-1
Construction Worker				
InhR	20	20	m^3/day	USEPA (1997a), Table 5-23 (Assumes heavy activity, 8 hours/day)
EF	250	250	days/year	USEPA (2002a), Exhibit 5-1
ED	0.5	1	years	BPJ; USEPA(2002a), Exhibit 5-1
Trespasser				
InhR	6	13	m^3/day	USEPA (1997a), Table 5-23 (Assumes heavy activity for 2 and 4 hours/day)
EF	50	100	days/year	BPJ
ED	3	6	years	BPJ

EXHIBIT C-6. EXTERNAL EXPOSURE FROM RADIONUCLIDES

$$Dose_{ext} = C_{soil} \times \left[EF/CF_{DY}\right] \times ED \times ACF \times \left[ET_o\left(ET_i \times GSF\right)\right] \qquad \text{Eq. C-7}$$

where,

$Dose_{ext}$ = dose from external exposure (pCi-yr/g)

C_{soil} = concentration of radionuclide in soil (pCi/g)

EF = exposure frequency (days/year)

CF_{DY} = conversion factor (days/year)

ED = exposure duration (years)

ACF = area correction factor (unitless)

ET_o = fraction of time spent outdoors (unitless)

ET_i = fraction of time spent indoors (unitless)

GSF = gamma shielding factor (unitless).

Parameter Values

Exposure Factor	Value		Units	Source
	CTE	RME		
Indoor Worker				
EF	250	250	days/year	USEPA (2002a), Exhibit 4-1
CF_{DY}	365	365	days/year	Conversion factor
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a); Exhibit 4-1
ACF	Specific to RA study area		unitless	--
ET_i	0.33	0.33	unitless	USEPA (2009b), Table 1 (Assumes 100% of 8 hour work day)
ET_o	0	0	unitless	USEPA (2009b), Table 1
GSF	0.4	0.4	unitless	USEPA (2009b), Table 1

Exposure Factor	Value		Units	Source
	CTE	RME		
Outdoor Worker				
EF	225	225	days/year	USEPA (2002a), Exhibit 4-1
CF_{DY}	365	365	days/year	Conversion factor
ED	7	25	years	USEPA (1997a), Table 1-2; USEPA (2002a); Exhibit 4-1
ACF	Specific to RA study area		unitless	--
ET_i	0	0	unitless	USEPA (2009b), Table 1
ET_o	0.33	0.33	unitless	USEPA (2009b), Table 1 (Assumes 100% of 8 hour work day)
GSF	0.4	0.4	unitless	USEPA (2009b), Table 1
Construction Worker				
EF	250	250	days/year	USEPA (2002a), Exhibit 5-1
CF_{DY}	365	365	days/year	Conversion factor
ED	0.5	1	years	BPJ; USEPA(2002a), Exhibit 5-1
ACF	Specific to RA study area		unitless	--
ET_i	0	0	unitless	USEPA (2009b), Table 1
ET_o	0.33	0.33	unitless	USEPA (2009b), Table 1 (Assumes 100% of 8 hour work day)
GSF	0.4	0.4	unitless	USEPA (2009b), Table 1
Trespasser				
EF	50	100	days/year	BPJ
CF_{DY}	365	365	days/year	Conversion factor
ED	3	6	years	BPJ
ACF	Specific to RA study area		unitless	--
ET_i	0	0	unitless	Assumes 0% of time, 2 and 4 hours/day
ET_o	0.083	0.167	unitless	Assumes 100% of time, 2 and 4 hours/day
GSF	0.4	0.4	unitless	USEPA (2009b), Table 1

APPENDIX D

PARTICULATE MODELING APPROACH

Airborne particulate concentrations will be calculated for dust emissions sources at the Site. There are two primary sources of dust emissions for the Site: wind erosion, and soil disturbances associated with construction activities. A tiered modeling approach that progresses from a simplified and upper-bound assessment to a refined and more accurate estimate of potential health risks is proposed for evaluating inhalation exposures related to airborne particulates released from the Site. This Appendix provides details on the initial tier proposed in the RAWP.

The airborne particulate concentrations will be calculated separately for dust emissions from wind erosion and from construction-related activities for all modeling tiers. Dust emissions from construction activities are assumed to occur for a limited period (i.e., no more than 1 year) whereas emissions from wind erosion can occur throughout the assumed exposure period for any receptor. For construction workers the airborne particulate concentrations for the risk assessment will be based solely on the emissions from construction related activities because the relative contribution from wind erosion would be insignificant. For all other receptors a time-weighted airborne particulate concentration will be calculated to reflect the combined emissions from short-term construction activities and long-term wind erosion.

CONSTRUCTION WORKER EXPOSURES

The first tier for estimating airborne particulate concentrations will be based on the simplified site-specific methods provided in the EPA *Supplemental Soil Screening Guidance* (USEPA 2002a). EPA (2002a) has identified vehicle traffic as the most significant contributor to fugitive dust emissions during construction activities. Dust emissions for construction activities will be based on assumed vehicle traffic over unpaved surface soil. A PEF equation is provided for estimating the chemical concentration in air associated with soil concentration in the surface soil of the source. Separate PEF equations are provided for construction workers and offsite residents. The PEF for construction workers assumes they are exposed within the area where soil disturbances are occurring. For construction workers the EPA provides the following equation for derivation of the PEF for construction activities under the simplified site-specific assessment (USEPA 2002a):

$$PEF_{SC} = Q / C_{SR} \times \frac{1}{F_D} \times \left[\frac{T \times A_R}{556 \times (W/3)^{0.4} \times \frac{(365-p)}{365} \times \sum VKT} \right] \qquad \text{Eq. D-1}$$

where,

$$\left(A_R = L_R \times W_R \times 0.092903\ m^2 / ft^2 \right) \qquad \text{Eq. D-2}$$

where,

PEF_{SC}	=	subchronic road particulate emission factor (m^3/kg)
Q/C_{SR}	=	inverse of the ratio of the 1-h geometric mean air concentration to the emission flux along a straight road segment bisecting a square site; (g/m^2-s per kg/m^3)
F_D	=	dispersion correction factor (unitless)
T	=	total time over which construction occurs (s)
A_R	=	surface area of contaminated road segment (m^2)
L_R	=	length of road segment (ft)
W_R	=	width of road segment (ft)
W	=	mean vehicle weight (tons)
p	=	number of days with at least 0.01 inches of precipitation (days/year)
VKT	=	sum of fleet vehicle kilometers traveled during the exposure duration (km).

The site-specific value for construction time will be matched to the exposure duration (i.e., 6 months for CTEs and 1 year for RMEs). For the hypothetical construction scenario the default assumption will be a development area of 5 acres for the CTE case and 10 acres for the RME case. The soil concentrations for COPCs will be based on the 95th UCL for the site assessment area soil for 0-10 ft bgs. A sensitivity analysis will be conducted for the model inputs to evaluate the uncertainty in the risk estimates. This analysis will include consideration of localized areas of elevated soil concentrations relative to the site assessment area 95th UCL. Table D-1 provides a summary of the values to be used for PEF model parameters shown above.

An integral part of the PEF equation is the dispersion factor, designated as Q/C_{SR} in the equation above. The dispersion factor provides an estimate of the dilution that occurs during transport from the emission source to the point of exposure once dust is released into the atmosphere. The dispersion factor is linked with PEF to calculate the airborne particulate concentration. For construction workers the dispersion factor equation for particulate emissions provided for construction activities for the simplified site-specific assessment is as follows (USEPA 2002a):

$$Q/C_{SR} = A \times \exp\left[\frac{(\ln A_s - B)^2}{C}\right] \qquad \text{Eq. D-3}$$

where,

Q/C_{SR}	=	inverse of the ratio of the 1-h geometric mean air concentration to the emission flux along a straight road segment bisecting a square site; (g/m^2-s per kg/m^3)
A	=	constant (12.9351, unitless)
A_S	=	aerial extent of site surface soil contamination (acres)
B	=	constant (5.7383, unitless)
C	=	constant (71.7711, unitless).

The only site-specific parameter in Equation D-3 is the source size. Given the PEF for the construction scenario is based on the area of development, the source default source area value (i.e., A_s) will be 5 acres for the CTE case and 10 acres for the RME case. Table D-1 provides the default values to be used to in Equation D-3.

OFFSITE RESIDENT AND OUTDOOR WORKER EXPOSURES

For offsite residents and outdoor workers, the PEF accounts for contributions from both construction and wind erosion. However, the fugitive dust emissions from construction activities are very brief relative to the emissions from wind erosion. Therefore, the PEF for offsite residents and onsite workers is designed to normalize the mass of fugitive dust released over the exposure duration for a given receptor. This normalization process provides a means to account for the significant differences in the amount of time during which each fugitive dust source operates. In the simplified site-specific approach provided by EPA (2002a) vehicle traffic on unpaved roads is used to estimate the fugitive dust emissions from construction activities. The dust emission equation for road traffic is given by:

$$M_{road} = 556 \times (W/3)^{0.4} \times \left[\frac{(365-p)}{365}\right] \times \sum VKT \qquad \text{Eq. D-4}$$

where,

M_{road}	=	unit mass emitted from unpaved road traffic (g)
W	=	mean vehicle weight (tons)
p	=	number of days per year with at least 0.01 in. of precipitation (days/year)

VKT = sum of fleet vehicle kilometers traveled during the exposure duration (km).

Table D-2 provides a summary of the values to be used for PEF model parameters shown above. The parameter values assumed for the outdoor worker and offsite resident are consistent with those assumed for the construction worker. The soil concentrations for COPCs will be based on the 95th UCL for the site assessment area for 0-10 ft bgs. A sensitivity analysis will be conducted for the model inputs to evaluate the uncertainty in the risk estimates. This analysis will include consideration of localized areas of elevated soil concentrations relative to the site assessment area 95th UCL used to evaluate the COPCs.

The dust emissions for vehicle traffic, M_{ROAD}, will be calculated using Equaiton D-4. For the wind erosion component of the fugitive dust emissions, M_{WIND}, EPA provides the following equation for the simplified site-specific approach (USEPA 2002a):

$$M_{wind} = 0.036 \times (1 - V) \times \left(\frac{U_m}{U_t}\right)^3 \times F(x) \times A_{surf} \times ED \times 8{,}760\ hr/yr \qquad \text{Eq. D-5}$$

where,

M_{wind} = unit mass emitted from wind erosion (g)

V = fraction of vegetative cover (unitless)

U_m = mean annual windspeed (m/s)

U_t = equivalent threshold value of windspeed at 7 m (m/s)

F(x) = function dependent on U_m/U_t derived from Cowherd et al. 1985 (as cited in USEPA 2002a); (unitless)

A_{surf} = aerial extent of site with undisturbed surface soil contamination (m^2)

ED = exposure duration (years).

The aerial extent for the wind erosion PEF will be based on the size of the site assessment area rather than the area of development as used in the construction PEF. This assumption ignores the fact that some areas of the site assessment area are likely to be impervious to wind erosion. The fraction of vegetative cover will be set at zero in the first tier analysis, which optimizes the potential for wind erosion emissions from the site assessment area. The soil concentrations for COPCs will be based on the 95th UCL for the site assessment area soils for 0-2 ft bgs. A sensitivity analysis will be conducted for the model inputs to evaluate the uncertainty in the

risk estimates. This analysis will include consideration of localized areas of elevated soil concentrations relative to the site assessment area 95th UCL used to evaluate the COPCs. A complete listing of the inputs values for the model parameters is presented in Table D-2.

The PEF for the offsite residents and outdoor workers is calculated using the following equation once the emissions have been calculated for construction and wind erosion sources (USEPA 2002a):

$$PEF_{off} = Q / C_{off} \times \frac{1}{J_T} \qquad \text{Eq. D-6}$$

where,

$$\left(J_T = \frac{M_{road} + M_{wind}}{A_{site} \times ED \times \left(3.1536 \times 10^7 \, s / yr\right)} \right) \qquad \text{Eq. D-7}$$

where,

PEF_{off} = offsite particulate emission factor (m^3/kg)

Q/C_{off} = inverse of the ratio of the geometric mean air concentration to the emission flux at the boundary of a square source; (g/m^2-s per kg/m^3)

$$= A * \exp\left[\frac{(\ln A_{SITE} - B)^2}{C} \right] \qquad \text{Eq. D-8}$$

J_T = total time-averaged emission flux (g/m^2-s)

M_{road} = unit mass emitted from unpaved road traffic (g)

M_{wind} = unit mass emitted from wind erosion (g)

A_{site} = aerial extent of site (m^2)

ED = exposure duration (years).

The dispersion factor in this equation assumes that the receptor is located at the edge of the emission source, which is appropriate for offsite residents but not outdoor workers. Outdoor workers are assumed to be exposed within the boundary of the wind erosion source area. Therefore, the dispersion factor for outdoor workers will be based on the value for outdoor workers provided by EPA (2002a). EPA (2002a) provides the necessary information to modify the dispersion factor to reflect the area source size and the climatic region where the exposure

occurs. We will modify the dispersion factor using the climate-related inputs provided by EPA for Las Vegas, NV. Despite these adjustments to the dispersion factor, the calculation will still provide an upper-bound estimate of the exposure point air concentration for residents due to the fact that they are assumed to spend their entire exposure period located at the edge of the fugitive dust emission sources. Inputs to PEF equations for offsite residents and outdoor workers are presented in Table D-2.

If the simplified site-specific approach to fugitive dust emissions dominates the overall risk estimates for a specific receptor, we will recalculate the EPCs using a more refined approach. The next level of refinement would be to conduct the detailed site-specific calculations of fugitive dust emissions as recommended by EPA (2002a). The basis for this more detailed site-specific approach for dust emissions would be the algorithms provided for such analysis in Appendix F of the EPA *Supplemental Soil Screening Guidance* (2002a).

The detailed site-specific approach allows for the application of considerably more site-specific variables in the emissions estimation, which should reduce the amount of over-estimation in the associated risks. If application of the detailed site-specific approach recommended by EPA yields inhalation risks that dominate the total site risks for a receptor, the next step we propose would be to conduct refined site-specific air modeling using an EPA approved model. Use of a site-specific refined air model would allow us to place receptors at the appropriate distances and directions from assumed dust emissions sources and use site-specific meteorological data to derive more accurate estimates of airborne particulate concentrations. The fugitive dust emission estimates developed from the detailed site-specific approach would be linked with the air model to develop the more refined estimate of the airborne particulate concentration.

Table D-1. Input Parameter Values Used to Develop Particulate Emission Factor for Construction Worker Exposure.

Parameter	Abbreviation	Units	CTE	RME	Source
Dispersion Factor [a]	Q/C_{SR}	g/m^2-s per kg/m^3	16.40	15.25	Equation E-19, EPA (2002a)
Constant used to calculate dispersion factor	A	unitless	12.9351	12.9351	Equation 5-6, EPA (2002a)
Constant used to calculate dispersion factor	B	unitless	5.7383	5.7383	Equation 5-6, EPA (2002a)
Constant used to calculate dispersion factor	C	unitless	71.7711	71.7711	Equation 5-6, EPA (2002a)
Areal extent of site surface soil contamination	A_S	acres	5	10	Assumed
Dispersion correction factor [b]	F_D	unitless	0.186	0.186	Equation E-16, EPA (2002a)
Total time over which construction occurs	t	hr	4,380	8,760	Appendix E
Width of road segment	W_R	ft	20	20	Assumed
Length of road segment [c]	L_R	ft	467	660	Assumed
Surface area of contaminated road segment [d]	A_R	m^2	867	1,226	Equation 5-5, EPA (2002a)
Mean vehicle weight	W	tons	8	8	Assumed [e]
Number of days with ≥ 0.01 inches of precipitation	p	days/year	29	29	NOAA (2007) [f]
Sum of fleet vehicle kilometers traveled during the exposure duration [g]	VKT	km	555	1,569	Assumed

Sources: NOAA. 2007. Local climatological data: annual summary with comparative data. National Oceanic and Atmospheric Administration.
USEPA. 2002a. Supplemental guidance for developing soil screening levels for Superfund sites. OSWER 9355.4-24. U.S. Environmental Protection Agency.

[a] Calculated as $Q/C_{sr} = A \times \exp[(\ln A_s - B)^2 / C]$.

[b] Calculated as $F_D = 0.1852 + (5.3537 / t) + (-9.6318 / t^2)$ where t is the construction time in units of hours.

[c] Calculated as the square root of the areal extent of the surfce soil contamination configured as a square.

[d] Calculated as $A_R = L_R \times W_R \times 0.092903\ m^2 / ft^2$.

[e] Assumes twenty 2-ton cars and ten 20-ton trucks traverse the Site daily.

[f] Based on normal precipitation data from National Weather Service station at McCarran International Airpot, Las Vegas, NV.

[g] Calculated as 30 vehicles x L_R ft per day x 3.048E-4 km / ft x 5 days / week x t weeks. Where t = 26 weeks for the CTE and 52 weeks for the RME.

Table D-2. Input Parameter Values Used to Develop Particulate Emission Factor for Onsite Worker and Offsite Residents.

Parameter	Abbreviation	Units	CTE	RME	Source
Mean vehicle weight	W	tons	8	8	Assumed
Number of days with ≥ 0.01 inches of precipitation	p	days/year	29	29	NOAA (2007) [a]
Sum of fleet vehicle kilometers traveled during the exposure duration [b]	VKT	km	555	1,569	Assumed
Fraction of vegetative cover	V	unitless	0	0	Assumed
Mean annual wind speed	U	m/s	3.9	3.9	NOAA (2007) [a]
Equivalent threshold value of windspeed at 7 m	U_T	m/s	11.32	11.32	Equation 5-11, EPA (2002a)
Function dependent on Um/Ut derived from Cowherd et al. (1985)	F(X)	unitless	0.194	0.194	Equation 5-11, EPA (2002)
Areal extent of site with undisturbed surface soil contamination	A_{surf}	m^2	607,050	607,050	Site-specific
Exposure Duration	ED	years	Worker = 7 Resident = 9	Worker = 25 Resident = 30	Appendix E, Exhibit E-3
Dispersion Factor for Offsite Resident [c]	Q/C_{OR}	g/m^2-s per kg/m^3	44.21	44.21	Exhibit D-4 [d], EPA (2002a)
Constant used to calculate dispersion factor for offsite resident	A_{OR}	unitless	12.1784	12.1784	Exhibit D-4 [d], EPA (2002a)
Constant used to calculate dispersion factor for offsite resident	B_{OR}	unitless	24.5606	24.5606	Exhibit D-4 [d], EPA (2002a)
Constant used to calculate dispersion factor for offsite resident	C_{OR}	unitless	296.4571	296.4571	Exhibit D-4 [d], EPA (2002a)
Dispersion Factor for Onsite Worker [e]	Q/C_{OW}	g/m^2-s per kg/m^3	34.60	34.60	Exhibit D-2 [d], EPA (2002a)
Constant used to calculate dispersion factor for onsite worker	A_{OW}	unitless	13.3093	13.3093	Exhibit D-2 [d], EPA (2002a)
Constant used to calculate dispersion factor for onsite worker	B_{OW}	unitless	19.8387	19.8387	Exhibit D-2 [d], EPA (2002a)
Constant used to calculate dispersion factor for onsite worker	C_{OW}	unitless	230.1652	230.1652	Exhibit D-2 [d], EPA (2002a)

Sources: Cowherd, C.G., G. Muleski, P. Engelhart, and D. Gillette. 1985. Rapid assessment of exposure to particulate emissions from surface contamination sites. EPA/600/8-85/002. U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, DC. (not seen, as cited in USEPA 2002a).
NOAA. 2007. Local climatological data: annual summary with comparative data. National Oceanic and Atmospheric Administration.
USEPA. 2002a. Supplemental guidance for developing soil screening levels for Superfund sites. OSWER 9355.4-24. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, DC.

[a] Based on normal precipitation data from National Weather Service station at McCarran International Airpot, Las Vegas, NV.
[b] Calculated as 30 vehicles x L_R ft per day x 3.048E-4 km / ft x 5 days / week x T weeks. Where T = 26 weeks for the CTE and 52 weeks for the RME.
[c] Calculated as $Q/C_{OR} = A_{OR} \times \exp[(\ln A_{surf} - B_{OR})^2 / C_{OR}]$. Note that A_{surf} is in acres for this calculation (i.e., 607,050 m^2 = 150 acres).
[d] Data for Las Vegas, NV used in calculations.
[e] Calculated as $Q/C_{OW} = A_{OW} \times \exp[(\ln A_{surf} - B_{OW})^2 / C_{OW}]$. Note that A_{surf} is in acres for this calculation (i.e., 607,050 m^2 = 150 acres).

APPENDIX E

VAPOR MODELING APPROACH

Vapor modeling from soil and/or groundwater at the Site may be used as an additional line of evidence to support evaluation of inhalation risks. This appendix provides details on the models and inputs that would be used to evaluate vapors released from Site soils and groundwater.

VAPOR RELEASED FROM SOIL

Inhalation exposures for volatile chemicals from soils will be evaluated for all worker and resident populations. For outdoor workers, residents and construction workers, the exposures will be based on the soil volatilization model provided in the EPA *Soil Screening Guidance* (USEPA 1996a). For indoor workers the exposure will be based on the Johnson and Ettinger model of vapor intrusion. Each of the volatilization models is described in the following text.

For outdoor workers, residents and construction workers, the inhalation exposure to volatile chemicals released from soil will be conducted using a VF approach. Like the PEF, the VF is composed of an emission component and a dispersion component. The volatilization component is based on a time-dependent equilibrium model that assumes an infinite source of contamination. The model predicts average flux rate over the period of exposure using the following equations (ODEQ 2003):

$$J_{SS}ave = C_{soil} \times \rho_b \times \sqrt{\frac{D_A}{\pi \times t_{vol} \times 3.16 \times 10^7 \, s/yr}} \qquad \text{Eq. E-1}$$

where,

$J_{ss}ave$ = average flux from surface soil (μg/cm²-s)

C_{soil} = surface soil concentration (mg/kg)

p_b = soil bulk density (g/cm³)

π = 3.1 (unitless)

t_{vol} = time over which volatilization flux is being averaged (yr).

$$D_A = \frac{\left(D_{air} \times n_a^{10/3} \times H'_{TS} + D_w \times n_w^{10/3}\right)}{n^2 \times \left(n_a \times H'_{TS} + n_w + \rho_b \times f_{oc} \times K_{oc}\right)} \qquad \text{Eq. E-2}$$

where,

D_A = apparent chemical-specific diffusion coefficient (cm^2/s)

D_{air} = chemical-specific diffusion coefficient in air (cm^2/s)

D_w = chemical-specific diffusion coefficient in water (cm^2/s)

f_{oc} = fraction of organic carbon in soil (unitless)

K_{oc} = chemical-specific organic carbon partition coefficient (cm^3/g)

n = total soil porosity (unitless)

n_a = air-filled porosity (unitless)

n_w = water-filled porosity (unitless)

p_b = soil bulk density (g/cm^3)

H'_{TS} = chemical-specific non-dimensional Henry's Law constant at system temperature (unitless).

$$= \frac{\exp\left[-\frac{\Delta H_{v,TS}}{R_C}\left(\frac{1}{T_S}-\frac{1}{T_R}\right)\right]H_R}{RT_S} \qquad \text{Eq. E-3}$$

where,

$\Delta H_{v,TS}$ = enthalpy of vaporization at the system temperature, (cal/mol)

R_C = universal gas constant (1.9872 cal/mol-K)

T_S = system temperature (K)

T_R = Henry's law constant reference temperature (K)

H_R = Henry's law constant at the reference temperature ($atm\text{-}m^3/mol\text{-}K$)

R = gas constant (8.205×10^{-5} $atm\text{-}m^3/mol\text{-}K$).

The AT for the volatilization modeling, t_{vol}, will match the ED for all receptors with the exception of subchronic exposures assumed for construction workers (i.e., less than 7 years). For subchronic exposures the averaging time will be set to 6 years to avoid overestimation of

the emissions that would occur by assuming a shorter averaging time. Modeling with shorter averaging times would in effect reflect a fresh spill rather than the older residual sources of contamination at the Site. Site-specific values will be used for the soil characteristics related to porosity and density. Chemical-specific soil concentrations based on the 95th UCL for the site assessment area mean in the upper portion of the vadose zone will be used as the input to the VF model. Table E-1 provides a summary of the input values for the parameters above, except for those that are chemical-specific. The non-dimensional Henry's law constant for each chemical will be calculated using the inputs and methods provided by USEPA (2004b) for modeling vapor intrusion using the Johnson and Ettinger model. Tables E-2 and E-3 provide details on the site-specific values used to develop default soil porosity and organic carbon values. The applicability of these default soil porosity and organic carbon values will be reviewed by comparing with data specific to a site assessment area should such data be available.

The dispersion factor portion of the VF model is based on air modeling conducted for a range of source sizes and climatic regions throughout the United States. We propose to use the dispersion factor developed by EPA (1996a) using meteorological data for Las Vegas, NV. In addition, we will modify the dispersion factor to reflect the overall Site area which is the assumed source extent for the modeling.

The flux rate of chemicals from the soil can be increased due to soils handling activities related to construction. EPA (2002a) has determined that the conservative nature of the infinite source model used to model volatilization from soil, which assumes that volatile contaminants are present at the soil surface, should be protective of offsite residents, even for periods of construction activities. A sensitivity analysis will be conducted to determine the potential increase in exposure and risk estimates based on the potential increase in the flux rate during construction activities. The sensitivity analysis will also compare the model predictions to other volatilization-related studies conducted within the immediate vicinity of the Site as a means to evaluate the uncertainty in the risk estimates.

For onsite indoor workers the inhalation exposure related to release of volatile organic chemicals in soil will be evaluated using the EPA's Johnson and Ettinger model (USEPA 2004b). The model predicts the rate of transport of volatile chemicals through the vadose zone and into indoor air. The transport through the vadose zone is a response to the concentration gradient modeld using Fick's First law. The diffusion is described by an effective diffusion coefficient that is based on chemical-specific diffusivity values and soil porosity. At the interface of the vadose zone and building foundation, the Johnson and Ettinger model uses an approximation of the convective flux to estimate the rate at which the vapors would be drawn into the indoor air. The infiltration rate of vapors from the soil is balanced with the exfiltration rate of gases from the above-ground portion of the building to estimate the steady-state indoor air concentration.

The model to be used for the risk assessment is contained in spreadsheets available from EPA. For this application the version that deals with soil sources will be used. The Johnson and Ettinger models available from EPA contain defaults for all of the physical parameter values needed to conduct the modeling. We propose to use site-specific parameters for physical properties required to describe soil and groundwater properties (e.g., porosity, vadose zone temperature, depth of soil contamination). The default building characteristics contained in the EPA Johnson and Ettinger models will be used in this evaluation. These include parameters such as vapor flow rate into the building, the building lateral footprint, indoor mixing height, and air exchange rate.

The input soil concentration for the COPCs evaluated in the vapor intrusion model will be based on the 95th UCL for the mean concentrations for the upper vadose zone soils in the site assessment area. A sensitivity analysis will be conducted for the model inputs to evaluate the uncertainty in the risk estimates. This analysis will include consideration of localized areas of elevated soil concentrations relative to the site assessment area 95th UCL. A complete listing of the inputs values for the model parameters, except for chemical-specific parameters, is presented in Table E-4.

VAPORS RELEASED FROM GROUNDWATER

Inhalation exposures to volatile chemicals in onsite groundwater will be evaluated for all worker and resident populations. For outdoor workers, residents and construction workers, the exposures will be based on the groundwater volatilization model provided in the EPA *Soil Screening Guidance* (USEPA 1996a). For indoor workers the exposure will be based on the Johnson and Ettinger model of vapor intrusion. Each of the volatilization models is described in the following text.

For outdoor workers, offsite residents and construction workers, inhalation exposures to volatile chemicals released from groundwater are assumed to occur in ambient air. A VF approach will be used to characterize this exposure. The volatilization model is a steady-state equilibrium model that describes the transport of vapors through the vadose zone and into ambient air. The model assumes that groundwater is the source of the vapors in the vadose zone and not the soil column. The vapor concentration at the top of the groundwater is calculated as follows:

$$C_{sv} = C_{gw} \times H'_{TS} \times 10^{-6} \frac{g}{\mu g} \times 10^{-3} \frac{L}{cm^3} \qquad \text{Eq. E-4}$$

where:

C_{sv} = soil vapor concentration at the top of the groundwater for volatile COPCs (g/cm^3)

C_{gw} = chemical concentration in groundwater (µg/L)

H'_{TS} = chemical-specific non-dimensional Henry's Law constant at system temperature (unitless).

The movement of the vapor is calculated based on Fick's first law. The diffusion is in response to the concentration gradient across the vadose zone and can be described by an effective diffusion coefficient. Assuming that the concentration of the chemical is zero at the top of the soil column optimizes the concentration gradient and allows the emission rate to be written as follows:

$$Q = D_{T_{eff}} \times \frac{C_{sv}}{L_w} \qquad \text{Eq. E-5}$$

where,

Q = flux rate of chemicals at the soil surface (g/cm^2-s)

D_{Teff} = chemical total effective diffusion coefficient (cm^2/s)

C_{SV} = soil vapor concentration at the top of the groundwater for volatile chemicals (g/cm^3)

L_W = distance from the groundwater to the soil surface (cm).

The total effective diffusion coefficient will be calculated based on a two component approach, as used in the soil vapor intrusion modeling via the Johnson and Ettinger model. The first component described is the effective diffusion across the capillary zone as follows:

$$D_{eff_{cap}} = \frac{\left(D_a \times n_{ac}^{10/3} \times H'_{TS}\right) + \left(D_w \times n_{wc}^{10/3}\right)}{H'_{TS} \times n_c^2} \qquad \text{Eq. E-6}$$

where,

$D_{eff_{cap}}$ = effective chemical diffusion coefficient in the capillary fringe (cm^2/s)

D_a = chemical diffusivity in air (cm^2/s)

n_{ac} = air-filled porosity in capillary zone (unitless)

H'_{TS} = chemical-specific non-dimensional Henry's Law constant at system temperature (unitless)

D_W = chemical diffusivity in water (cm^2/s)

n_{wc} = water-filled porosity in capillary zone (unitless)

n_c = total porosity in capillary zone (unitless).

The vadose zone represents the second component of the total effective diffusion coefficient. The following equation will be used for the vadose zone:

$$D_{eff_v} = \frac{\left(D_a \times n_{av}^{10/3} \times H'_{TS}\right) + \left(D_w \times n_{wv}^{10/3}\right)}{H'_{TS} \times n_v^2} \qquad \text{Eq. E-7}$$

where,

D_{eff_v} = effective chemical diffusion coefficient in the vadose zone (cm^2/s)

D_a = chemical diffusivity in air (cm^2/s)

n_{av} = air-filled porosity in the vadose zone (unitless)

H'_{TS} = chemical-specific non-dimensional Henry's Law constant at system temperature (unitless)

D_w = chemical diffusivity in water (cm^2/s)

n_{wv} = water-filled porosity in the vadose zone (unitless)

n_v = total porosity in capillary zone (unitless).

The total effective diffusion coefficient is then calculated as follows:

$$D_{T_{eff}} = \frac{L_w}{\left(\frac{L_v}{D_{eff_v}}\right) + \left(\frac{L_c}{D_{eff_c}}\right)} \qquad \text{Eq. E-8}$$

where,

$D_{T_{eff}}$ = total effective chemical diffusion coefficient (cm^2/s)

L_w = distance from top of groundwater to soil surface (cm)

L_v = length of vadose zone (cm)

L_c = length of capillary zone (cm).

The dispersion factor for groundwater volatilization to ambient air will be based on a dilution factor presented by EPA (1996a). The dilution factor was based on the modeling conducted using the Industrial Source Complex air dispersion model. The air dispersion model was run for a range of square area sources from 0.5 acres to 30 acres in size. A unit flux rate (i.e., 1 g/m^2-sec) was used in the model to generate normalized ambient air concentrations at the center of the source area (i.e., kg/m^3 per g/m^2-sec). The normalized air concentrations will be used with site assessment area-specific volatilization flux rates to yield the associated ambient air concentrations. Normalized ambient air concentrations were calculated for 29 locations throughout the United States, including Las Vegas, NV. The model results for Las Vegas, NV will be used in this risk assessment. The dilution factor selected for use in the risk assessment will be adjusted to reflect the area of the relevant groundwater source for the site assessment area.

The volatilization and dispersion factor will be combined to calculate the ambient air concentration at the center of the source as follows:

$$C_a = \frac{Q \times CF}{DF} \qquad \text{Eq. E-9}$$

where:

C_a	=	chemical ambient air concentration (mg/m^3)
Q	=	flux rate of chemicals at the soil surface (g/cm^2-s)
DF	=	ambient air dilution factor (g/m^2-sec per kg/m^3)
CF	=	conversion factor = 10^6 mg/kg

For onsite indoor workers the infiltration of volatile chemicals from groundwater into indoor air will be evaluated using EPA's Johnson and Ettinger model (USEPA 2004b). The model predicts the rate of transport of volatile chemicals through the vadose zone and into indoor air. The transport through the vadose zone is modeled as a response to the concentration gradient using Fick's First law. The diffusion is described by an effective diffusion coefficient that is based on chemical-specific diffusivity values and soil porosity. At the interface of the vadose zone and building foundation, the Johnson and Ettinger model uses an approximation of the convective flux to estimate the rate at which the vapors would be drawn into the indoor air. The infiltration rate of vapors from the soil is balanced with the exfiltration rate of gases from the above-ground portion of the building to estimate the steady-state indoor air concentration.

The model to be used for the risk assessment is contained in spreadsheets available from EPA. For this application the version that deals with groundwater sources will be used. The Johnson and Ettinger models available from EPA contain defaults for all of the physical parameter values needed to conduct the modeling. We propose to use site-specific parameters for physical

properties required to describe soil and groundwater properties (e.g., porosity, vadose zone temperature, depth to groundwater). The default building characteristics contained in the EPA Johnson and Ettinger models will be used in this evaluation. These include parameters such as vapor flow rate into the building, the building lateral footprint, indoor mixing height, and air exchange rate.

The input groundwater concentration for the COPCs evaluated in the vapor intrusion model will be based on the 95th UCL for the mean site assessment area concentrations. A sensitivity analysis will be conducted for the model inputs to evaluate the uncertainty in the risk estimates. This analysis will include consideration of localized areas of elevated groundwater concentrations relative to the site assessment area 95th UCL. A complete listing of the inputs values for the model parameters, except for chemical-specific parameters, is presented in Table E-4.

Table E-1. Input Parameter Values to be Used to Develop Volatilization Factor from Soil/Groundwater to Ambient Air.

Parameter	Abbreviation	Units	CTE	RME	Source
Soil dry bulk density	ρ_b	g/cm^3	1.72	1.72	Site-specific [a]
Averaging time for volatilization	t_{vol}	year	Worker = 7 Resident = 9	Worker = 25 Resident = 30	Appendix E, Exhibit E-3
Fraction of organic carbon in soil	f_{oc}	unitless	0.004	0.004	Site-specific [b]
Total soil porosity in vadose zone	$\acute{\eta}_v$	unitless	0.347	0.347	Site-specific [a]
Air-filled soil porosity in vadose zone	$\acute{\eta}_{va}$	cm^3/cm^3	0.255	0.255	Site-specific [a]
Water-filled porosity in vadose zone	$\acute{\eta}_{vw}$	cm^3/cm^3	0.092	0.092	Site-specific [a]
Total soil porosity in capillary zone	$\acute{\eta}_c$	unitless	0.384	0.384	EPA (2004b) [c]
Soil air-filled soil porosity in capillary zone	$\acute{\eta}_{ca}$	cm^3/cm^3	0.238	0.238	EPA (2004b) [c]
Soil water-filled porosity in capillary zone	$\acute{\eta}_{cw}$	cm^3/cm^3	0.146	0.146	EPA (2004b) [c]

Source: USEPA. 2004b. User's guide for evaluating subsurface vapor intrusion into buildings. EPA Contract Number: 68-W-02-33. Work Assignment No. 004. PN 030224.0002. Prepared for Industrial Economics Incorporated, Cambridge, MA. For submittal to U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. Environmental Quality Management, Inc., Durham, NC.

Notes: USCS = Unified Soil Classification System

[a] Values based on site specific values shown in Table E-2.

[b] Value based on site-specific values shown in Table E-3.

[c] Based on silt/clay USCS classification (i.e., ML) for samples in soil borings from near water table leading to use of porosity values for sandy clay loam from EPA (2004b).

Table E-2. Site-Specific Geochemical Parameters for Vadose Zone Soils used to Develop Model Input Parameter Values.

									Summary for SM Soils Only [a]			
Soil Boring ID	Depth (ft bgs)	Lithology (mean grain size)	Moisture Content (% wt)	Dry bulk density (g/cm^3)	Water-filled porosity [b]	Total soil porosity	Air-filled porosity [c]	Sample USCS Classification [d]	Water-filled porosity	Total porosity	Air-filled porosity	Dry Bulk density (g/cm^3)
SB-EC3	5.8	medium sand	7.17	1.68	0.120	0.364	0.244	SM	0.120	0.364	0.244	1.68
	15.3	medium sand	6.54	1.54	0.101	0.415	0.314	SM	0.101	0.415	0.314	1.54
	35.3	medium sand	31.65	1.43	0.453	0.443	-0.010	CL	NA	NA	NA	NA
SB-EC4	5.3	medium sand	7.78	1.6	0.124	0.393	0.269	SM	0.124	0.393	0.269	1.6
	16.3	medium sand	8.92	1.57	0.140	0.395	0.255	SM	0.140	0.395	0.255	1.57
	35.3	medium sand	5.36	1.57	0.084	0.398	0.314	ML	NA	NA	NA	NA
SB-EC8	6.3	coarse sand	3.56	1.84	0.066	0.297	0.231	SM	0.066	0.297	0.231	1.84
	17.3	coarse sand	3.7	1.8	0.067	0.32	0.253	SM	0.067	0.320	0.253	1.8
	35.8	coarse sand	3.04	1.89	0.057	0.295	0.238	SM	0.057	0.295	0.238	1.89
SB-EC9	5.8	medium sand	4.11	1.74	0.072	0.339	0.267	SM	0.072	0.339	0.267	1.74
	16.3	medium sand	4.49	1.71	0.077	0.352	0.275	SM	0.077	0.352	0.275	1.71
	35.8	medium sand	4.1	1.71	0.070	0.34	0.270	ML	NA	NA	NA	NA
SB-EC10	5.8	medium sand	4.19	1.69	0.071	0.349	0.278	SM	0.071	0.349	0.278	1.69
	15.3	coarse sand	2.37	1.81	0.043	0.306	0.263	SM	0.043	0.306	0.263	1.81
	35.8	gravel	4.54	1.78	0.081	0.329	0.248	SM	0.081	0.329	0.248	1.78
SB-EC11	5.8	medium sand	7.39	1.64	0.121	0.381	0.260	SM	0.121	0.381	0.260	1.64
	15.3	medium sand	7.28	1.89	0.138	0.296	0.158	SM	0.138	0.296	0.158	1.89
	35.8	coarse sand	5.75	1.67	0.096	0.374	0.278	SM	0.096	0.374	0.278	1.67
						Average for soils with SM classfication			0.092	0.347	0.255	1.72

Source: PES. 2007. Data transmittal report: results of additional vadose zone characterization, former Stauffer Chemical Company facility, Henderson, Nevada. PES Environmental Inc., Novato, CA.

Notes:
CL = clays of low to medium plasticity with or without sand or gravel
ML = silts of low to medium plasticity with or without sand or gravel
NA = not applicabe
SM = silty sands with or without gravel
USCS = Unified Soil Classification System

[a] Averages based on SM classification only to be consistent with dominant site characterizaiton for vadose zone.
[b] Calculated as [Moisture Content (% wr) / 100] x [Dry Bulk Density (g/cm^3) / Water Density (g/cm^3)] where Water density = 1.0 g/cm^3.
[c] Calculated as Total Soil Porosity - Water-filled Porosity.
[d] Based on soil boring logs.

Table E-3. Calculation of Site-Specific Fraction Organic Carbon (f_{oc}).

Soil Boring ID	Sample Depth Interval (ft bgs)	Reported TOC (mg/kg)	TOC with 1/2 RL for Non Detects (mg/kg)	TOC for Detectes Only (mg/kg)
SB-EC1	0.5 - 1	1230	1230	1230
SB-EC1	9.5 - 10	< 1000	500	ND
SB-EC1	39 - 39.5	570	570	570
SBEC2	0.5 - 1	3190	3190	3190
SBEC2	7 - 7.5	< 1000	500	ND
SBEC2	25 - 25.5	< 1000	500	ND
SBEC2	39 - 39.5	< 1000	500	ND
SB-EC3	0.5 - 1	7180	7180	7180
SB-EC3	7 - 7.5	< 1000	500	ND
SB-EC3	25 - 25.5	16900	16900	16900
SB-EC3	34 - 34.5	< 1000	500	ND
SB-EC4	0.8 - 1.3	1150	1150	1150
SB-EC4	7 - 7.5	< 1000	500	ND
SB-EC4	25 - 25.5	< 1000	500	ND
SB-EC4	35.5 - 36	< 1000	500	ND
SB-EC5	1.5 - 2	1690	1690	1690
SB-EC5	7 - 7.5	790	790	790
SB-EC5	25 - 25.5	< 1000	500	ND
SB-EC5	49 - 49.5	< 1000	500	ND
SB-EC6	0 - 0.5	700	700	700
SB-EC6	7 - 7.5	1140	1140	1140
SB-EC6	25.5 - 26	590	590	590
SB-EC6	47 - 47.5	530	530	530
SB-EC7	0 - 0.5	44900	44900	44900
SB-EC7	7 - 7.5	< 1000	500	ND
SB-EC7	25.5 - 26	< 1000	500	ND
SB-EC7	45.5 - 46	< 1000	500	ND
SB-EC8	0 - 0.5	< 1000	500	ND
SB-EC8	7 - 7.5	570	570	570
SB-EC8	25 - 25.5	< 1000	500	ND
SB-EC8	39.5 - 40	< 1000	500	ND
SB-EC9	0 - 0.5	1010	1010	1010
SB-EC9	7.5 - 8	550	550	550
SB-EC9	25 - 25.5	< 1000	500	ND
SB-EC9	41 - 41.5	< 1000	500	ND
EC10	0 - 0.5	770	770	770
EC10	7 - 7.5	6920	6920	6920
EC10	25.5 - 26	< 1000	500	ND
EC10	40 - 40.5	< 1000	500	ND
EC11	0.8 - 1.3	< 1000	500	ND
EC11	7 - 7.5	< 1000	500	ND
EC11	25.5 - 26	< 1000	500	ND
EC11	41 - 41.5	5440	5440	5440
EC12	4.5 - 5	6240	6240	6240
EC12	7 - 7.5	2950	2950	2950
EC12	25 - 25.5	10100	10100	10100
EC12	41 - 41.5	31400	31400	31400

Table E-3. Calculation of Site-Specific Fraction Organic Carbon (f_{oc}).

Soil Boring ID	Sample Depth Interval (ft bgs)	Reported TOC (mg/kg)	TOC with 1/2 RL for Non Detects (mg/kg)	TOC for Detectes Only (mg/kg)
EC13	0.8 - 1.3	1940	1940	1940
EC13	7 - 7.5	1040	1040	1040
EC13	27 - 27.5	1090	1090	1090
EC13	40 - 40.5	590	590	590
EC14	1 - 1.5	26900	26900	26900
EC14	7 - 7.5	7760	7760	7760
EC14	23.5 - 24	7500	7500	7500
EC14	40 - 40.5	< 1000	500	ND
		Average TOC	3742	6444
		Estimated f_{oc}	0.0037	0.0064

Source: PES. 2007. Data transmittal report, results of additional vadose zone characterization, Former Stauffer Chemical Company Facility, Henderson, Nevada. PES Environmental Inc., Novato, CA. March 26. Appendices D and J.

Notes:
f_{oc} = fraction organic carbon
ft bgs = feet below ground surface
RL = reporting limit
TOC = total organic carbon
< = non-detected concentration, value shown is reporting limit

Table E-4. Input Parameter Values to be Used in Johnson and Ettinger Model for Indoor Worker Exposure.

Parameter	Abbreviation	Units	CTE	RME	Source
Average soil temperature	T_S	° C	15.5	15.5	EPA (2004b), Figure 8
Average groundwater temperature	T_w	° C	13.9	13.9	EPA (2004b), Figure 8
Depth below grade to bottom of enclosed space floor	L_F	cm	15	15	EPA (2004b), Table 9 [a]
Depth below grade to top of contamination	L_t	cm	15	15	EPA (2004b), Table 9 [a]
Depth below grade to bottom of contamination in soil	L_b	cm	1433	1433	Appendix C, Table C-2 [b]
Depth below grade to water table	L_w	cm	1433	1433	Appendix C, Table C-2
Enclosed space floor thickness	Lcrack	cm	10	10	EPA (2004b), Table 9
Soil-building pressure differential	ΔP	Pascals	4	4	EPA (2004b), Table 9
Vapor flowrate into building	Q_{soil}	L/min	5	5	EPA (2004b)
Enclosed space floor length	LB	cm	1000	1000	EPA (2004b), Table 9
Enclosed space floor width	WB	cm	1000	1000	EPA (2004b), Table 9
Enclosed space height	HB	cm	244	244	EPA (2004b), Table 9
Floor-wall seam crack width	WB	cm	0.1	0.1	EPA (2004b), Table 9
Indoor air exchange rate	ER	1/h	1.0	1.0	CalEPA 2005
Thickness of soil stratum A (vadose zone)	hA	cm	1433	1433	Appendix C, Table C-2 [b]
Soil type for vadose zone	SCS soil type	unitless	Loamy Sand (LS)	Loamy Sand (LS)	Site-specific [c]
Soil dry bulk density for vadose zone	ρ_b	g/cm^3	1.72	1.72	Site-specific [c]
Total soil porosity for vadose zone	$\acute{\eta}_v$	unitless	0.347	0.347	Site-specific [c]
Soil water-filled porosity for vadose zone	$\acute{\eta}_{vw}$	cm^3/cm^3	0.092	0.092	Site-specific [c]
Soil air-filled porosity for vadose zone	$\acute{\eta}_{va}$	cm^3/cm^3	0.255	0.255	Site-specific [c]
Soil organic carbon fraction for vadose zone	foc	unitless	0.004	0.004	Site-specific [d]
Soil type for capillary zone	SCS soil type	unitless	Sandy Clay Loam (SCL)	Sandy Clay Loam (SCL)	EPA (2004b), Appendix C [e]
Total soil porosity for capillary zone	$\acute{\eta}_c$	unitless	0.384	0.384	EPA (2004b), Appendix C [e]
Soil water-filled porosity for capillary zone	$\acute{\eta}_{cw}$	cm^3/cm^3	0.146	0.146	EPA (2004b), Appendix C [e]
Soil air-filled porosity for capillary zone	$\acute{\eta}_{ca}$	cm^3/cm^3	0.238	0.238	EPA (2004b), Appendix C [e]

Source: USEPA. 2004b. User's guide for evaluating subsurface vapor intrusion into buildings. EPA Contract Number: 68-W-02-33. Work Assignment No. 004. PN 030224.0002. Prepared for Industrial Economics Incorporated, Cambridge, MA. For submittal to U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. Environmental Quality Management, Inc., Durham, NC.

CalEPA. 2005. Guidance for the evaluation and mitigation of subsurface vapor intrusion to indoor air. Interim Final. California Environmental Protection Agency, Department of Toxic Substances Control, CA. December 15, 2004, Revised February 7, 2005. 105 pp.

Notes: USCS = Unified Soil Classification System

[a] Assumes slab on grade construction.

[b] Assumes entitre vadose zone is impacted.

[c] Values based on site specific values shown in Table E-2.

[d] Value based on site-specific values shown in Table E-3.

[e] Based on silt/clay USCS classification (i.e., ML) for samples in soils borings from near water table leading to use of porosity values for sandy clay loam from EPA (2004b).

APPENDIX F

PARAMETERS FOR EVALUATING ASBESTOS-INDUCED RISKS

Table F-1. Optimized Dose-Response Coefficients for Pure Fiber Types.

Fiber Type	K_L x 100	K_M x 10^8
Chrysotile	0.6	0.04
Amphibole	3	30

Source: Table 7-18 from USEPA. 2003c. Technical support document for a protocol to assess asbestos-related risk. Final Draft. U.S. Environmental Protection Agency.

Notes: K_L = coefficient for lung cancer
K_M = coefficient for mesothelioma
Coefficients apply to exposures quantified in terms of concentrations (f/ml) of fibers longer than 10 um and thinner than 0.4 um

Table F-2. Estimated Additional Deaths[a] from Lung Cancer or Mesothelioma from Constant Lifetime Exposure to 0.0001 TEM f/cc Longer than 10 um and Thinner than 0.04 um Based on Optimum Risk Coefficients.

	Non-smokers		Smokers	
	Males	Females	Males	Females
Chrysotile				
Lung Cancer	0.185	0.207	1.6	1.5
Mesothelioma	0.0836	0.096	0.0482	0.0702
Combined	0.269	0.303	1.65	1.57
Amphibole				
Lung Cancer	0.2	0.286	2.22	2.47
Mesothelioma	62.7	72.3	36.1	52.7
Combined	62.9	72.5	38.3	55.1

Source: Table 8-2 from USEPA. 2003c. Technical support document for a protocol to assess asbestos-related risk. Final Draft. U.S. Environmental Protection Agency.

Notes: TEM = transmission electron microscopy
[a] Estimated additional deaths are per 100,000 persons.