and in February, May, September, and November 2006. Soil and groundwater sampling locations are provided on Figures 2 and 3 as well as Appendix C to the Phase II report. Data sets for all media were reviewed for the identification of hot spots (i.e., discrete areas with constituent levels 10- to 100-fold higher than the surrounding areas). However, no sampling locations were identified as "hot spots."

Soil. Analytical surface soil data from 2002 samples ME-1A (0-4'), ME-2A (3'), ME-4A (0-4'), TP-1A (0-4'), TP-2A (0-4'), TP-3A (0-4'), and TP-4B (0-7.5'), 2003 samples SB-1S (0-4'), SB-2S (0-4'), SB-3S (0-4'), and SB-4S (0-4'), and 2006 samples MEB-1 (0-2), MEB-2 (0-1.5), MEW-3 (0-2.2) plus its duplicate, MEW-4 (0-2.5), MEW-5 (0-2.7), MEB-6 (0-3), MEW-7 (1-1.7), MEB-8, (1-3.2), MEW-9 (0.5-3), MEB-10 (2-3), ESMB-1 (0-4), ESMB-2 (0-4), ESMB-3 (0-4), ESMB-4 (0-4), and ESMB-5 (0-4) were used to evaluate random, areal, outdoor exposures for the current use scenarios.

Analytical subsurface soil data from 2002 samples ME-1B (4-12'), ME-2B (4-12'), ME-4B (4-14'), TP-2B (4-7') and its duplicate, and TP-3B (4-9'), 2003 samples SB-1D (4-10.5'), SB-2D (4-12'), SB-3D (4-12'), and SB-4D (4-8') and its duplicate, and 2006 samples MEB-1 (4-6), MEB-2 (4-7), MEW-3 (4-7.5), MEW-4 (4-8), MEW-5 (4-8), MEB-6 (4-8), MEW-7 (4-7.5), MEB-8, (4-7.4), MEW-9 (4-8), MEB-10 (4-8) plus its duplicate, ESMB-1 (4-8), ESMB-2 (4-8), ESMB-3 (4-8), ESMB-4 (4-8), and ESMB-5 (4-8) in conjunction with the surface soil samples listed above, were used to evaluate random, areal, future outdoor exposures under the assumption that future activities result in the movement of soil constituents to equally accessible locations. The analytical results for the individual surface and subsurface soil samples are presented in the Phase II report.

Samples ME-3B (4-12'), MEB-11 (0.5-3' and 4-8'), MEB-12 (0.5-3' and 4-8'), MEB-13 (0-3' and 4-8'), and MEB-14 (0-3' and 4-8') were collected from areas beyond the disposal site boundary and have not been used in the development of exposure point concentrations.

Data for site-wide surface soil contaminants are presented in Table 1 in the form of the frequency of detection and minimum and maximum detected concentrations. These data were used in the

development of the soil exposure point concentrations for the current trespasser and town worker scenarios. For the future scenarios, data for surface and subsurface soil contaminants are combined and presented in Table 2. These data were used in the development of the soil exposure point concentrations for the future trespasser, on-site worker, construction worker, and child and adult resident exposure scenarios. In addition, these data were also used to model indoor and outdoor air volatile compound concentrations for the future on-site worker, construction worker, and resident scenarios.

Groundwater. To assess current groundwater conditions, quarterly groundwater monitoring was conducted in 2006 from monitoring wells MEW-3, MEW-4, MEW-7, MEW-9, and P-3. Groundwater samples were also collected from three monitoring wells (ME-1, ME-2 and ME-4) in June 2002. The 2002 samples have not been quantitatively evaluated because they are unlikely to be representative of current groundwater conditions at the site. However, the 2002 data are qualitatively discussed relative to the 2006 data in Section 2.5. The locations of the groundwater monitoring wells are shown on Figure 3. Monitoring wells ME-3 and MW-5 are located beyond and upgradient of the disposal site boundary and have not been used in the development of exposure point concentrations. Groundwater analytical data collected in 2002 and 2006 are presented in the Phase II report. Summarized analytical data for the 2002 and 2006 groundwater data sets are presented in Tables 3 and 4, respectively.

Maximum analyte concentrations detected in on-site wells in 2006 were also used to model groundwater contaminant discharge to the surface waters of the Quaboag River for the recreational scenario. Consistent with MassDEP guidance, a default dilution/attenuation factor of 10-fold was applied to the groundwater contaminant concentrations to estimate applicable current/future surface water exposure point concentrations in the downgradient wetland. Table 4 presents the estimated surface water exposure point concentrations (see Section 2.3 for additional discussion).

2.1.1 Chemicals of Potential Concern. COPCs for the Risk Characterization may be identified by: a) screening contaminant levels against available or applicable background values, b)

eliminating contaminants with low detection frequencies and low concentrations, and c) eliminating contaminants that are considered laboratory constituents and not related to the release. In addition, contaminants that are not detected above laboratory reporting limits may also be removed from further consideration as COPCs. Information regarding laboratory reporting limits, data quality, and data usability can be found in the Phase II report.

Contaminants detected in surface soil samples summarized in Table 1 were identified as COPCs, except for benzo(b)fluoranthene, fluoranthene, indeno(1,2,3-cd)pyrene, phenanthrene, pyrene, arsenic, cadmium, and magnesium which were eliminated as COPCs based on a comparison to MassDEP background levels. In addition, calcium, potassium, and sodium were eliminated from further evaluation as COPCs because they are essential nutrients and unlikely to exhibit toxicity at the levels detected. For surface and subsurface soils combined, benzo(a)anthracene and benzo(a)pyrene were additionally eliminated as COPCs based on a comparison to MassDEP background levels (Table 2). For groundwater and surface water (Table 4), all detected chemicals were considered COPCs for the evaluation of risk of harm to human receptors.

To select COPCs for the indoor air pathway, atmospheric concentrations of the volatile compounds detected in soil were modeled from maximum soil concentrations to estimate maximum indoor air concentrations (Table 5). The maximum indoor air concentrations were compared to applicable MassDEP background concentrations for indoor air (Table 6). In the absence of specific indoor air background values, VOCs were considered COPCs. Based on this comparison, C_9-C_{12} aliphatics, C_9-C_{18} aliphatics, and phenanthrene were selected as COPCs for the indoor air pathway. No MassDEP outdoor air background values are available. Therefore, all VOCs detected in soil were considered COPCs for the outdoor air exposure pathway (Table 7). For the evaluation of risk associated with the air pathways, indoor and outdoor air concentrations were modeled from soil EPCs (Tables 7 and 8), to generate indoor and outdoor air EPCs, presented in Table 9 (see Section 2.3.3 for additional discussion).

2.2 DOSE-RESPONSE ASSESSMENT

The Dose-Response Assessment is designed to evaluate the potential non-carcinogenic (threshold) and carcinogenic (non-threshold) effects of the COPCs and describes the effects observed in humans and/or laboratory animals following the intake of a specific dose of the compound. The information from the Dose-Response Assessment is used in conjunction with information from the Exposure Assessment (Section 2.3) to estimate the risk and hazard generated by each COPC from an exposure (Section 2.4).

2.2.1 Non-Carcinogenic Dose-Response Assessment The toxicity values used in this Dose-Response Assessment of COPCs producing non-carcinogenic effects are the Reference Doses (RfDs) for oral and dermal exposures and the Reference Concentrations (RfCs) for inhalation exposures. RfD and RfC values provide an estimate of the daily dose of the COPC to which an individual may be exposed without an appreciable risk of adverse health effects, including organ damage or reproductive effects, appearing during their lifetime. RfD and RfC values assume that a threshold dose exists below which there will be minimal risk for adverse effects to occur.

The chronic RfD and RfC values are based upon a 70-year lifetime exposure, and are approximate doses derived from an available No Observed Adverse Effect Level (NOAEL) or the Lowest Observed Adverse Effect Level (LOAEL). Subchronic RfD values are based on defined, less than lifetime exposures.

Uncertainty factors, which account for varying sensitivities among populations and extrapolation of data from animal studies to humans, and modifying factors, which reflect professional judgment of the toxicity information available, are applied to the NOAEL or LOAEL to determine RfD and RfC values. These safety factors reflect the quality of the data used and build conservatism into the Dose-Response Assessment.

Relative Absorption Factors (RAFs) are used to account for differences between the method of administration in the study on which the RfD or RfC is based and the site-specific routes of exposure. These values vary with the medium and with the route of exposure.

The RfD and RfC values used in this Risk Characterization were selected by giving primary consideration to values used by MassDEP in the development of the MCP numerical standards (MassDEP, 2006). When toxicity values could not be obtained from this source (e.g., for copper), values were obtained from the *U.S. EPA's Integrated Risk Information System (IRIS)* (US EPA, 2007a) or the *Superfund Technical Support Center* (STSC). The chronic and subchronic RfDs and RfCs are listed in Tables 10 and 11, respectively, and the RAFs are listed in Table 12. Chemical and physical property information for COPCs is summarized in Table 13.

2.2.2 Carcinogenic Dose-Response Assessment The U.S. EPA has developed a system for classifying chemicals according to the likelihood that the compound is a human carcinogen. This system groups chemicals into five classes based upon the weight-of-evidence (of carcinogenicity) of the available data. COPCs identified as group A, B, or C carcinogens are evaluated in a Method 3 Risk Characterization. Based on the classification of the COPCs (Tables 10 and 11 for oral and inhalation exposures, respectively), the carcinogenic effects of dibenz(a,h)anthracene and Aroclor-1260 were evaluated in this risk characterization. Beryllium, chromium, and nickel were additionally evaluated for carcinogenic effects via the inhalation route of exposure. The oral and inhalation slope factors (SFs) and unit risks (URs) used in this risk characterization were selected by giving primary consideration to values used by MassDEP in the development of the MCP numerical standards (MassDEP, 2006).

2.3 EXPOSURE ASSESSMENT

To characterize the risk of harm from contact with a COPC, an exposure assessment is conducted to identify exposure profiles and to estimate the EPCs. Consistent with the requirements of 310 CMR 40.0923, the exposure assessment requires the identification of all current and reasonably foreseeable activities and uses associated with a site and its surrounding environment, and a description of how these uses and activities could result in the exposure of human receptors to the COPCs present. The latter descriptions are known as exposure profiles and are developed to provide an estimate of the type and magnitude of potential exposures to COPCs, the frequency

and intensity of the exposure, and the pathways and routes by which receptors may be exposed to the COPC, and to provide an estimate of the EPC.

For the characterization of risk of harm to human health under a Method 3 Risk Characterization, the exposure profile and EPC are used to estimate chemical intake from which the hazard index and excess lifetime cancer risk may be calculated. The exposure profiles and the estimation of chemical intake are integral parts of the exposure assessment and are discussed separately below.

2.3.1 Exposure Profiles Exposure Profiles for potential receptors are presented here, based on actual and anticipated site activities and uses.

Under current site conditions, the most-likely routes and pathways of exposure to COPCs for the adolescent trespasser/recreational user are:

- incidental ingestion of and dermal contact with surface soils;
- inhalation of fugitive dust entrained from friable surface soils; and
- incidental ingestion of and dermal contact with surface water.

Current town workers intermittently accessing the site may be exposed directly to COPCs in surface soil via incidental ingestion, dermal contact, and inhalation of fugitive dust.

Under future site conditions, involving subsurface excavations, the most-likely routes and pathways of exposure to COPCs for construction workers are:

- incidental ingestion of and dermal contact with soil;
- inhalation of vapors from soil in outdoor air;
- inhalation of fugitive dust entrained from friable soils; and
- incidental ingestion of and dermal contact with shallow groundwater.

Future adolescent trespassers/recreational users may be exposed via the same routes and pathways described for the current adolescent trespassers/recreational users. Future on-site workers (e.g., parking lot attendants), in addition to being exposed via the inhalation of vapors migrating to indoor air, may be exposed incidentally to COPCs in exposed soils through incidental ingestion, dermal contact, and inhalation of soil-derived dusts.

Under a worst-case future scenario, involving construction of a residence on the site, child and adult residents could be exposed by the same direct routes and pathways described above for the adolescent trespasser/recreational user. In addition, future residents may be exposed via inhalation of volatiles migrating from soil to indoor air and ingestion of homegrown fruits and vegetable grown on-site. As a short-cut, future resident direct contact soil exposures are assumed to approximate a future park scenario for young child and adult soil exposures.

The exposure points, routes, and pathways evaluated in this risk characterization for the current adolescent trespasser/recreational user, current town worker, future adolescent trespasser/recreational user, future on-site worker, future construction worker, and future resident receptors are summarized in Table 14. As a conservative short-cut, the construction worker is assumed to be representative of a utility worker. This approach is valid since a utility worker who contacts contaminated media during the installation of a utility trench is less exposed than a construction worker, contacting contaminated media throughout the duration of a building construction project. If construction worker exposures are determined to be acceptable, then utility worker exposures would also be acceptable.

2.3.2 Exposure Assumptions and Quantitative Estimates of Exposure Based on the site-specific exposure profiles discussed in Section 2.3.1, the following exposure assumptions were developed, and quantitative estimates of exposure identified for use in the calculation of the chemical intake values. Exposure assumptions are provided in Table 15 for the adolescent trespasser/recreational user (current and future), town worker (current), on-site worker (future), construction worker (future), adult resident (future), and child resident (future). Table 16 provides documentation for the calculation of receptor-specific Normalized Average Daily Contact Rates (NADSCRs) and Normalized Average Daily Intake Rates (NADSIRs) used in

exposure estimation for noncarcinogenic effects. For carcinogenic effects, Normalized Lifetime Average Daily Contacts Rates (NLADCRs) and Normalized Lifetime Average Daily Intake Rates (NLADIRs) were used to estimate exposure. These receptor-specific values are calculated in Table 17.

Exposure assumption values listed represent either actual site-specific information, U.S. EPA values from the *Office of Solid Waste and Emergency Response (OSWER) Directives*, or values considered either consistent with or those listed in MassDEP's *Guidance For Disposal Site Risk Characterization* (July 1995), *Residential Scenario Shortform* (December 1997), or Technical Updates (2002b and 2002d).

Current and Future Adolescent Trespasser/Recreational User Under current and future site activities and uses, exposures to COPCs could occur as a result of exposure to soil on-site and surface water in the downgradient wetlands. Principal receptors are expected to be adolescent children trespassing and/or playing on-site and in the nearby surface water body.

Potential exposures to COPCs in surface water are assumed to occur 1 hr/day for 52 days/year. The latter represents an exposure frequency of 2 days/week for the warmest six months of the year. The primary routes of COPC exposure are expected to be incidental ingestion and dermal contact with impacted surface water. The average trespasser is identified as a child, age 11-16 years, 51.8 kg average body weight. The incidental ingestion rate was set at 50 ml/hour for surface water. Dermal contact with surface water was assumed to be likely via hands, forearms, lower legs, and feet (4820 cm^2).

Current adolescent trespassers could also be exposed to the COPCs in surface soil at the site, while future adolescent trespassers may be exposed to COPCs in both surface and subsurface soils. Incidental ingestion of soil was set at 50 mg/day. Dermal contact with COPCs in soil was considered likely via the hands, forearms, and feet (2928 cm^2) with a soil adherence factor of 0.14 mg/cm^2 for youth trespassers. Inhalation of fugitive dusts outdoors by children was evaluated using a PM_{10} of 32 ug/m^3 and an inhalation rate of 0.8 m^3/hour. Otherwise, exposure

assumptions for this exposure pathway are the same as those used for surface water exposures (e.g., 52 days/year). The exposure duration for non-cancer endpoints of toxicity was averaged over 7 years for the trespasser.

Current Town Worker and Future On-Site Worker Under this scenario, exposures to COPCs could occur through low level outdoor activities (e.g., placement/removal of stockpiles or monitoring of parking) should current and future workers contact exposed impacted soils.

For the current town worker, outdoor exposures to COPC in soil are assumed to occur 1 hour/day for 23 days/year. The latter period represents an exposure frequency of 2 days/week for the warmest 3 months of the year. Future workers are assumed to contact soil 8 hours per day for 125 days/year, under the assumption that the site is used as an unpaved parking lot. Inhalation of fugitive dusts outdoors by adults was evaluated using a PM_{10} of 32 ug/m^3 and an inhalation rate of 1.2 m^3/hr. The exposure duration for non-cancer endpoints of toxicity was averaged over 25 years for the worker. The average weight of the adult was set at 70 kg. Incidental ingestion of soil was set at 50 mg/day. Dermal contact with COPCs in soil was considered likely via the hands, forearms, face, and feet (3477 cm^2) with soil adherence factors of 0.18 mg/cm^2 (value for light construction worker) and 0.03 mg/cm^2 (value for outdoor worker) for the current and future worker, respectively. The future on-site worker was also conservatively assumed to be exposed to contaminants in indoor air, following subsurface migration from soil. Indoor exposures are assumed to occur 8 hours/day for 250 days/year.

Future Construction Worker Under future foreseeable site activities and uses, exposures to COPCs could occur during subsurface excavations that expose impacted soils. Principal receptors are expected to be workers involved in the construction of a new building or in trenching activities for the installation or repair of utilities.

Assumptions used in the modeling of COPCs from soil to outdoor air include the construction worker working close to the bottom of a trench with dimensions of 30 feet long, 3 feet wide, and 4 feet deep, and an air exchange rate of 60/hour (Table 7).

Under a worst-case scenario for outdoors, potential exposures to COPCs are assumed to occur 8 hours/day over 125 days/year. The period of 125 days/year represents the typical number of workdays in one year in this area. The exposure duration for non-cancer endpoints was averaged over 1 year. The primary routes of COPC exposure are expected to be incidental ingestion and dermal contact for impacted soil and inhalation of fugitive dusts entrained from COPC-impacted friable soils. Workers are identified as adult males, 70 kg average body weight. The incidental ingestion rate of soil was conservatively set at 100 mg/day and dermal contact with COPCs likely via the hands, forearms, feet and face for soil (3477 cm^2). A soil adherence factor of 0.29 mg/cm^2 was also used for dermal contact with soil by the construction worker. Inhalation of fugitive dusts outdoors by adult workers was evaluated using a PM_{10} of 60 ug/m^3, an inhalation rate of 3.6 m^3/hour, and an exposure time of 8 hours/day. Excavations were assumed to proceed down to the water table. The incidental groundwater ingestion rate was set at 6.25 ml/hr (total 50 ml/incident), and dermal contact likely via the hands, forearms, feet, and face.

Future Adult and Child Resident Under a worst-case future residential land use scenario, exposures to COPCs at the on-site residence could occur through indoor activities, working or playing in the yard, and recreational activities (e.g., wading) in nearby surface waters.

For the adult resident, outdoor exposures to COPCs in soil are assumed to occur 1 hour/day for 109 days/year. The latter period represents an exposure frequency of 5 days/week for the warmest 5 months of the year. The exposure duration of 1 hour/day is based on the U.S. EPA estimation of 5 hours/week of outdoor activities for the average adult. For the child outdoor scenario, potential exposures to COPCs in soil are assumed to occur 1.5 hour/day for 153 days/year.

Inhalation of fugitive dusts outdoors by adults and children was evaluated using a PM_{10} of 32 ug/m^3 and inhalation rates of 1.2 m^3/hr and 0.36 m^3/hr, respectively. For the fruit and vegetable consumption pathway, assumptions contained in the *Residential Scenario Shortform* (MassDEP,

1997) were used. Exposures to contaminants in indoor air were assumed to occur for 24 hours/day for 350 days/year.

The exposure duration for non-cancer endpoints of toxicity was averaged over 30 years for the adult and 7 years for the child. The average weight of the adult and child were set at 70 kg and 15 kg, respectively. Incidental ingestion of soil was set at 50 mg/day and 100 mg/day for the adult and child, respectively. Dermal contact with COPCs in soil was considered likely via the hands, arms, legs, face, and feet for the child (2434 cm^2; soil adherence factor of 0.35 mg/cm^2) and hands, forearms, lower legs, feet, and face for the adult (5657 cm^2; soil adherence factor of 0.13 mg/cm^2).

Potential future exposures to surface water COPCs are assumed to occur 1 hour/day for 52 days/year and 109 days/year for the adult and child, respectively. The primary routes of COPC exposure are expected to be incidental ingestion and dermal contact with impacted surface water. The incidental ingestion rate of surface water was set at 50 ml/hour and dermal contact likely via the same body areas as described for soil exposures.

2.3.3 Exposure Point Concentrations Exposure Point Concentrations (EPCs) represent the COPC concentrations in a medium that a receptor may come in contact with at the exposure point. Depending on the exposure scenario, the exposure point may consist of an area or zone of potential exposure, or a single exposure point. As described in 310 CMR 40.0926(3), the objective in estimating EPCs is to identify a conservative estimate of the average concentration of each COPC in each exposure medium that may be contacted by a receptor at an exposure point over the period of exposure. EPCs for this risk characterization were derived from the analytical soil data tabulated in Tables 1 and 2, groundwater and modeled surface water data tabulated in Table 4, and modeled air data presented in Table 9.

For chronic and subchronic exposures to soil and groundwater, the lower of the 95% Upper Confidence Limit (UCL) on the arithmetic mean concentration or the maximum detected concentration has been used as the EPC. The 95% UCLs were calculated using EPA's software

program "ProUCL Statistical Software" (Version 3.0; U.S. EPA, 2002 and 2004a). ProUCL tests for normality, lognormality, and gamma distribution of a data set, and computes a conservative and stable 95% UCL of the population mean. Based on the data distribution, ProUCL computes the 95% UCL of the population mean using five parametric and ten non-parametric statistical methods. The 95% UCL values could be calculated by this program if four or more samples were available for summarization from an exposure point. When less than four samples were available for an exposure point, the program was unable to calculate a 95% UCL value. When the 95% UCL value for a COPC exceeded the maximum detected concentration because of small sample size or high variability or if the 95% UCL values could not be calculated (< 4 samples), the maximum detected value was used as the EPC for the scenario. Consistent with current MassDEP guidance, levels of COPCs reported as "below the reporting limit" were assigned a value of one-half the reporting limit in the calculation of the 95% UCL.

For fugitive dust exposures, soil EPCs were used to estimate airborne concentrations of COPCs entrained from friable soils to evaluate inhalation exposures for applicable receptors. To evaluate the potential impact of groundwater to surface water discharge of COPCs into the Quaboag River, the 95% UCL COPC concentrations for groundwater were evaluated. Surface water EPCs were derived by dividing the COPC groundwater 95% UCL concentrations by 10 to account for the dilution/attenuation that would occur during discharge. 95% UCL soil concentrations for volatile compounds were used to model indoor and outdoor air EPCs for the future resident and construction worker scenarios. Medium-specific EPCs are presented in Tables 1 and 2 for soil, Table 4 for groundwater and surface water, and Table 9 for indoor and outdoor air.

2.3.4 Estimation of Chemical Intake To evaluate the risk of harm to human health, the intake of each COPC must be estimated and involves assessing the amount of material in contact with the receptor and the amount actually available for absorption by the body. This assessment is achieved through the calculation of an average daily dose (ADD) for each COPC and for each route of exposure. Compound-specific and exposure route-specific RAFs are used in the ADD

equations to convert an exposure (amount) to a dose (amount per unit body weight). The RAFs are listed in Table 12.

The general ADD equation is as follows and is consistent with those provided in MassDEP's *Guidance for Disposal Site Risk Characterization (July, 1995)*:

$$\text{ADD} = \frac{\text{Total Amount of Chemical Taken In}}{(\text{Body Weight}) * (\text{Averaging Period})}$$

The specific ADD equations for the various exposure pathways evaluated are provided below:

Inhalation of Indoor/Outdoor Air

$$\text{ADD} = \frac{(\text{EPC})*(\text{Exposure Time})*(\text{Exposure Frequency})*(\text{Exposure Duration})}{(\text{Averaging Period})}$$

Incidental Ingestion of Soil, Groundwater, or Surface Water

$$\text{ADD} = \frac{(\text{EPC})*(\text{Ingestion Rate})*(\text{Exposure Frequency})*(\text{Exposure Duration})*\text{RAF}}{(\text{Body Weight})*(\text{Averaging Period})}$$

Dermal Contact with Soil

$$\text{ADD} = \frac{(\text{EPC})*(\text{Surface Area})*(\text{Exposure Frequency})*(\text{Exposure Duration})*(\text{Adherence Factor})*\text{RAF}}{(\text{Body Weight})*(\text{Averaging Period})}$$

Dermal Contact with Groundwater or Surface Water

$$\text{ADD} = \frac{(\text{EPC})*(\text{Surface Area})*(\text{Exposure Frequency})*(\text{Exposure Time})*(\text{Exposure Duration})*\text{RAF}*K_p}{(\text{Body Weight})*(\text{Averaging Period})}$$

For the fugitive dust pathway, equations presented in *Characterization of risks due to inhalation of particulates by construction workers (Final Technical Update; 2002)* were used. The equations used are as follows:

Inhalation of Fugitive Dust – GI System

$$\text{ADD/LADD} = \frac{(\text{EPC})*2*(\text{InhalationRate})*\text{RAF}*(\text{ExposureTime})*(\text{ExposureFrequency})*(\text{ExposureDuration})*PM_{10}}{(\text{Body Weight})*(\text{Averaging Period})}$$

Inhalation of Fugitive Dust – Respiratory System

$$ADD/LADD = \frac{(EPC)*0.5*(InhalationRate)*RAF*(ExposureTime)*(ExposureFrequency)*(ExposureDuration)*PM_{10}}{(Body\ Weight)*(Averaging\ Period)}$$

The averaging period (AP), or period of time over which the total intake of constituent is averaged, can be adjusted to calculate the ADD for an acute exposure (AP = 1 day or less), for a subchronic exposure (AP = few days - several months), for a chronic exposure (AP = several months - somewhat less than lifetime), and for a lifetime exposure (AP = 70 years). The exposure frequencies, exposure durations, and averaging periods used in this risk characterization are listed in Table 15 for the current and future adolescent trespasser/recreational user, current town worker, future on-site worker, future construction worker, future adult resident, and future child resident.

The ADD values calculated for chronic/subchronic exposures were compared to the toxicity values (e.g., RfDs or SFs) discussed in Section 2.2. This comparison provides a numerical estimate of the levels of risk and the potential for adverse health effects to occur due to exposure to COPCs, as described in the next subsection.

2.4 RISK CHARACTERIZATION

To characterize the risk of harm to human health from potential exposures to the COPCs identified at the site, non-carcinogenic and carcinogenic risks were characterized for each COPC present at each exposure point for each receptor, and the cumulative receptor risk values compared to the MassDEP risk limits to assess whether a condition of no significant risk exists at the site. In addition, the condition of no significant risk was evaluated through comparison of EPCs for the COPCs to Applicable, Available, or Suitably Analogous Public Health Standards.

2.4.1 Non-Carcinogenic Risk Characterization To estimate non-carcinogenic risk, the hazard quotient for each COPC was calculated by dividing the average daily dose (ADD) computed in the Exposure Assessment by the RfD or RfC identified in the Dose-Response Assessment. The total site risk for each receptor was subsequently calculated by summing the

hazard indices (HIs) for the applicable exposure scenarios. The value was then compared to the total site non-carcinogenic risk limit (total site HI) of 1 (310 CMR 40.0993(6)) to characterize the risk of harm to human health, and to establish whether a condition of no significant risk exists as defined in 310 CMR 40.0993(7).

A summary of the risk findings for the receptors is shown in Table 18.

Hazard Index for the Current Adolescent Trespasser/Recreational User. The total site HI for this receptor is 0.1, which does not exceed the MassDEP Risk Limit of 1. The total site HI consists of 0.07 for the incidental ingestion of surface soil; 0.05 for dermal contact with surface soil; 0.0009 for the inhalation of fugitive dust; 0.0001 for incidental ingestion of surface water; and 0.000003 for dermal contact with surface water. Individual COPC pathway and route-specific Hazard Quotients are shown in Tables 19, 21, and 23.

Hazard Index for the Current Town Worker. The total site HI for this receptor is 0.05, which does not exceed the MassDEP Risk Limit of 1. The total site HI consists of 0.02 for the incidental ingestion of surface soil; 0.03 for dermal contact with surface soil; and 0.0004 for the inhalation of fugitive dusts. Individual COPC pathway and route-specific Hazard Quotients are shown in Tables 25 and 27.

Hazard Index for the Future Adolescent Trespasser/Recreational User. The total site HI for this receptor is 0.1, which do not exceed the MassDEP Risk Limit of 1. The total site HI consists of 0.08 for the incidental ingestion of soil; 0.05 for dermal contact with soil; 0.001 for the inhalation of fugitive dust; 0.0001 for incidental ingestion of surface water; and 0.000003 for dermal contact with surface water. Individual COPC pathway and route-specific Hazard Quotients are shown in Tables 23, 29, and 31.

Hazard Index for the Future Construction Worker. The total site HI for this receptor is 0.5, which does not exceed the MassDEP Risk Limit of 1. The total site HI consists of 0.3 for the incidental ingestion of soil; 0.1 for dermal contact with soil; 0.1 for the inhalation of fugitive

dust; 0.002 for incidental ingestion of groundwater; 0.0003 for dermal contact with groundwater; and 0.000007 for inhalation of volatile compounds in outdoor air. Individual COPC, pathway and route-specific Hazard Quotients are shown in Tables 33, 35, 37, and 39.

Hazard Index for the Future On-Site Worker. The total site HI for this receptor is 0.4, which does not exceed the MassDEP Risk Limit of 1. The total site HI consists of 0.1 for the incidental ingestion of soil; 0.02 for dermal contact with soil; 0.02 for the inhalation of fugitive dust; and 0.2 for inhalation of volatile compounds in indoor air. Individual COPC, pathway and route-specific Hazard Quotients are shown in Tables 41, 43, and 45.

Hazard Index for the Future Child Resident. The total site HI for this receptor is 4, which exceeds the MassDEP Risk Limit of 1. The total site HI consists of 2 for the incidental ingestion of soil; 1 for dermal contact with soil; 0.007 for the inhalation of fugitive dust; 0.2 for ingestion of home grown fruits and vegetables; 0.0009 for incidental ingestion of surface water; 0.000009 for dermal contact with surface water; and 0.9 for inhalation of volatile compounds in indoor air. The exceedance of the MassDEP Risk Limit is primarily due to the presence of lead in soil. Individual COPC pathway and route-specific Hazard Quotients are shown in Tables 47, 49, 51, 53, and 55.

Hazard Index for the Future Adult Resident. The total site HI for this receptor is 1, which does not exceed the MassDEP Risk Limit of 1. The total site HI consists of 0.1 for the incidental ingestion of soil; 0.1 for dermal contact with soil; 0.003 for the inhalation of fugitive dust; 0.00009 for incidental ingestion of surface water; 0.000002 for dermal contact with surface water; and 0.9 for inhalation of volatile compounds in indoor air. Individual COPC pathway and route-specific Hazard Quotients are shown in Tables 57, 59, 61, and 63.

2.4.2 Carcinogenic Risk Characterization To calculate the Excess Lifetime Cancer Risk (ELCR) for each COPC, the Lifetime Average Daily Dose (LADD) estimated in the Exposure Assessment was multiplied by the Slope Factor (SF) or Inhalation Unit Risk (UR) identified in the Dose-Response Assessment. The ELCR for each COPC was then summed to calculate the

total ELCR for each exposure scenario. The total site cancer risk for each receptor was subsequently computed by summing the total ELCR values for the applicable exposure scenarios. The total site cancer risk was then compared to the MassDEP total site cancer risk limit of 1E-05 (310 CMR 40.0993(6)) to characterize the risk of harm to human health, and to establish whether a condition of no significant risk exists at the site, as defined in 310 CMR 40.0993(7).

A summary of the risk findings is shown in Table 18.

Carcinogenic Risk for the Current Adolescent Trespasser/Recreational User. The total site ELCR calculated for this receptor is 4E-08, which does not exceed the MassDEP Risk Limit of 1E-05. The total site ELCR consists of 2E-08 for incidental ingestion of surface soil; 1E-08 for dermal contact with surface soil; and 4E-09 for inhalation of fugitive dusts. No carcinogenic COPCs were identified in surface water samples. Individual COPC pathway and route-specific ELCRs are shown in Tables 20, 22, and 24.

Carcinogenic Risk for the Current Town Worker. The total site ELCR calculated for this receptor is 5E-08, which does not exceed the MassDEP Risk Limit of 1E-05. The total site ELCR consists of 2E-08 for the incidental ingestion of surface soil; 2E-08 for dermal contact with surface soil; and 8E-09 for the inhalation of fugitive dusts. Individual COPC pathway and route-specific ELCRs are shown in Tables 26 and 28.

Carcinogenic Risk for the Future Adolescent Trespasser/Recreational User. The total site ELCR calculated for this receptor is 3E-08, which does not exceed the MassDEP Risk Limit of 1E-05. The total site ELCR consists of 2E-08 for incidental ingestion of soil; 1E-08 for dermal contact with soil; 3E-09 for inhalation of fugitive dusts. No carcinogenic COPCs were identified in surface water samples. Individual COPC pathway and route-specific ELCRs are shown in Tables 24, 30, and 32.

Carcinogenic Risk for the Future Construction Worker. The ELCR calculated for this receptor is 7E-08, which does not exceed the MassDEP Risk Limit of 1E-05. The total site ELCR consists

of 8E-09 for the incidental ingestion of soil; 8E-09 for dermal contact with soil; and 5E-08 for the inhalation of fugitive dusts. No carcinogenic COPCs were identified for groundwater or outdoor air. Individual COPC, pathway and route-specific ELCRs are shown in Tables 34, 36, 38, and 40.

Carcinogenic Risk for the Future On-Site Worker. The total site ELCR for this receptor is 4E-07, which does not exceed the MassDEP Risk Limit of 1E-05. The total site ELCR consists of 1E-07 for the incidental ingestion of soil; 2E-08 for dermal contact with soil; and 2E-07 for the inhalation of fugitive dusts. No carcinogenic COPCs were identified for indoor air. Individual COPC, pathway and route-specific ELCRs are shown in Tables 42, 44, and 46.

Carcinogenic Risk for the Future Resident. The total site ELCR for the future child/adult resident is 8E-06 which does not exceed the MassDEP Risk Limit of 1E-05. The total site ELCR consists of 4E-07 for the incidental ingestion of soil; 4E-07 for dermal contact with soil; 5E-08 for the inhalation of fugitive dusts; and 8E-06 for the ingestion of home grown fruits and vegetables. No carcinogenic COPCs were identified for surface water or indoor air. Individual COPC pathway and route-specific ELCRs are shown in Tables 48, 50, 52, 54, 56, 58, 60, 62, and 64.

2.4.3 Applicable or Suitably Analogous Public Health Standards As part of the evaluation of the condition of no significant risk of harm to human health, as defined in 310 CMR 40.0993(7), the MCP requires a comparison of COPC EPCs to Applicable or Suitably Analogous Public Health Standards (310 CMR 40.0993(3)). Such standards include, but are not limited to, Massachusetts *Air Quality Standards* promulgated in 310 CMR 6.00, Massachusetts *Surface Water Quality Standards* promulgated in 314 CMR 4.00, and Massachusetts *Drinking Water Quality Standards* promulgated in 310 CMR 22.00.

Site groundwater is not classified into the GW-1 category. Therefore, comparison of COPC groundwater concentrations to MassDEP *Drinking Water Standards* as Applicable Standards (consistent with the requirements of 310 CMR 40.0993(3)) is not required for the evaluation of

significant risk of harm to human health since the drinking water standards are not considered applicable.

Since the surface water bodies at the site are not classified as Class A or B surface water bodies, comparison of COPC surface water EPCs to *Massachusetts Surface Water Quality Standards* promulgated in 314 CMR 4.00 is not required. In addition, comparison of surface water COPC concentrations to U.S. EPA *Ambient Water Quality Criteria* for the human consumption of fish was not considered applicable for this site.

2.5 UNCERTAINTY ANALYSIS

Risk characterizations are subject to a number of uncertainties. As a result, risk estimates derived from the equations and assumptions in this risk characterization should not be interpreted as absolute estimates of the risk of harm to human health posed by potential exposures to COPCs detected at the site.

General sources of uncertainty include:

- adequacy of the site characterization;
- adequacy of the sampling plan;
- quality and treatment of the analytical data;
- modeling of EPCs;
- accuracy of the exposure assumptions; and
- development of toxicity values (RfDs, RfCs).

Specific uncertainties and steps to reduce the level of uncertainty are discussed below:

2.5.1 Hazard Identification Constituents may be removed from consideration as COPCs, if the levels detected do not exceed available background values. Modeled indoor air concentrations of 2-methylnaphthalene and C_{11}-C_{22} aromatics were removed from further

consideration since modeled atmospheric concentrations for these compounds, in the presence of a semi-permeable concrete slab, did not exceed MassDEP indoor air background levels. Likewise, arsenic, cadmium, magnesium, and some PAHs were eliminated as soil COPCs because their maximum soil levels did not exceed the MassDEP soil background levels for native soils.

2.5.2 Dose-Response Assessment In the Dose-Response Assessment, the use of an Uncertainty Factor and a Modifying Factor, which are applied by the U.S. EPA and MassDEP to toxicity information to obtain RfD and RfC values, are used to account for the following uncertainties, which, in turn, can add to the overall uncertainty of the risk characterization findings:

- the use of dose-response information from effects observed at high doses to predict the adverse health effects that may occur following exposure to the low levels expected from human contact with the COPCs in the environment;
- the use of dose-response information from short-term exposure studies to predict the effects of long-term exposures, and vice-versa;
- the use of dose-response information from animal studies to predict adverse health effects in humans; and
- the use of dose-response information from homogeneous animal populations or healthy human populations to predict the adverse health effects likely to be observed in the general population, consisting of individuals with a wide range of sensitivities.

An additional uncertainty that likely resulted in overestimation of risk and hazard is the use of toxicity values for hexavalent chromium to evaluate total chromium analyses in the absence of speciation data.

2.5.3 Exposure Assessment The Exposure Assessment focuses on the evaluation of non-carcinogenic and carcinogenic effects for an individual who is maximally exposed to the COPC.

Generally, conservative exposure assumptions are used for exposure concentrations, frequency and duration of exposure. These conservative assumptions can potentially overestimate and result in compounding conservatism in the estimate of the risk of harm from exposure to the COPC and contribute to the uncertainty of the risk characterization. In addition, default exposure assumption values were used for daily ingestion rates, breathing rates, body weights, and exposed surface areas. The use of default values for these parameters likely resulted in a health-protective evaluation.

In the absence of monitoring data for indoor and outdoor air quality at the site, models were used to predict atmospheric COPC concentrations. Although three commonly accepted models were used to estimate volatilization of COPCs from soil, and dilution and dispersion in air, conservative input variables (e.g., semi-permeable slab; 0.5 air exchanges/day) were used, which can also introduce uncertainty into the risk findings. In addition, a default dilution/attenuation factor was used to estimate surface water concentrations after groundwater discharge to the nearby surface water bodies. However, use of these models and default values with conservative assumptions tends to be overprotective of human health, rather than underestimating potential risk.

Groundwater data collected from site monitoring wells in 2002 were not quantitatively evaluated in the risk characterization due to age of data and the likelihood that these data are no longer representative of current site conditions. The 2002 groundwater data are summarized in Table 3 and qualitatively discussed below:

- Two organics (acetone and MTBE) were detected at concentrations (9.6 ug/L and 1.1 ug/L, respectively) at least three orders of magnitude below their applicable Method 1 groundwater standards (50,000 ug/L). In addition, acetone was detected as a lower concentration than that detected in the upgradient well, ME-3 (50 ug/L).
- The detected concentrations of the essential nutrients calcium, magnesium, potassium, and sodium are unlikely to be toxic to humans at the levels present.
- The maximum detected concentrations of zinc (3.9 ug/L) and manganese (381.5 ug/L) were less than those detected in the upgradient well, ME-3 (5.6 ug/L and 672 ug/L,

respectively). In addition, the zinc detection was less than its applicable Method 1 groundwater standard (900 ug/L).

- The maximum detected concentration of barium (85 ug/L) was less than its applicable Method 1 groundwater standard (50,000 ug/L).
- Cobalt (15.5 ug/L), iron (617 ug/L) and aluminum (595 ug/L) were detected at levels that exceeded the upgradient wells, ME-3 and MW-5. However, these levels are unlikely to pose a hazard to construction workers or recreational users following discharge to surface water since the detected concentrations are below risk-based values (U.S. EPA, 2004b) protective of drinking water exposures (73 ug/L, 1100 ug/L, and 3600 ug/L, respectively).

3.0 PUBLIC WELFARE RISK CHARACTERIZATION

Risk of harm to public welfare from exposures to COPCs detected at the site was characterized in accordance with 310 CMR 40.0994, under the current and reasonably foreseeable site activities and uses. Factors evaluated included: nuisance conditions (e.g., odors), unilateral restrictions on the use of other properties and degradation of public or private drinking water resources as a result of the COPC release. In addition, COPC soil and groundwater maximum detected concentrations were compared to their respective Upper Concentration Limits (UCLs) listed in 310 CMR 40.0996(7) (Tables 65 and 66). None of the soil or groundwater maximum concentrations exceed their respective UCLs. Therefore, the site is considered to meet the condition of no significant risk of harm to public welfare as defined in 310 CMR 40.0994.

4.0 CHARACTERIZATION OF RISK TO SAFETY

Risk of harm to safety, associated with the release of COPCs at the site, was evaluated in accordance with the requirements of 310 CMR 40.0941(2) and 40.0960, and was based on a site visit and on observations made consistent with MCP Response Action Performance Standards (RAPS) as defined in 310 CMR 40.0191. COPC-related safety hazards evaluated under current

and future foreseeable site conditions included: the presence of open pits; uncontained corrosive, flammable/ignitable, reactive, or infectious materials; threat of fire or explosion, including the presence of explosive vapors; and rusted or corroded drums or containers.

Qualitative observations revealed the presence of hazards at the site, including unstable slopes along the former mill foundation and glass and rusted metal debris littering the site. These conditions are likely to pose a threat of physical harm or bodily injury to trespassers at the site, and therefore, a condition of significant risk of harm to safety was considered to exist at the site.

Evaluation of risk of harm to safety through comparison of site conditions to applicable or suitably analogous safety standards (e.g., Lower Explosive Limits) was not considered applicable to this site.

5.0 ENVIRONMENTAL RISK CHARACTERIZATION

Characterization of risk of harm to the environment associated with the site was conducted using a Stage I Environmental Screening as defined in 310 CMR 40.0995(3) and MassDEP (1996). The objective of the Stage I Environmental Screening is to identify those exposure pathways (links between contaminant sources and ecological receptors) that require further quantitative assessment and those that do not.

This Stage I Environmental Screening evaluates surface water risk by comparing surface water COPC concentrations to conservative toxicological benchmarks. Surface water COPC concentrations were estimated by a 10-fold dilution of groundwater COPCs concentrations. If the conservative benchmarks are not exceeded, then it can be presumed that no significant hazard exists.

5.1 SITE ECOLOGICAL CHARACTERIZATION AND POTENTIAL EXPOSURE PATHWAYS

Two independent ecological units were identified as potential exposure areas that require further discussion and characterization.

Environmental receptors that may be impacted by COPCs at the site, either directly or indirectly through migration of the COPCs, can include habitats and biota, such as Areas of Critical Environmental Concern (ACECs) and threatened and/or endangered species or species of special concern.

The entire project area and adjacent lands are mapped as containing Estimated (EH 817) and Priority Habitat (PH 12) of Rare Species by the Massachusetts Natural Heritage and Endangered Species Program (NHESP). In response to M&E's October 2007 information request letter, NHESP listed the following six species as occurring within the vicinity of the project area: American Bittern (*Botaurus lentignosus*), an endangered bird species; Long's Bulrush (*Scirpus longii*), a threatened plant species; Pied-billed grebe (*Podilymbus podiceps)*, an endangered bird species; sedge wren (*Cistothorus platensis)*, an endangered bird species; bridle shiner *(Notropis bifrenatus)*, a fish species of special concern; and Blue-spotted salamander *(Ambystoma laterale)*, an amphibian species of special concern. (see NHESP correspondence in Appendix B of the Phase II report).

A site walkover was completed to identify any aquatic or terrestrial habitats, or wildlife on or adjacent to the site and to characterize any vegetation present. The investigation focused on the 59-67 Mill Street property (see site walkover memo provided in Appendix B of the Phase II report).

5.1.1 Terrestrial Exposure Area. The terrestrial exposure area is essentially rectangular in shape and approximately 0.75 acre in area. In general, the area is highly disturbed as evidenced by sporadic piles of partially buried metal and construction debris (bricks, concrete, etc.) as well

as piles of sand, rock, and wood chips. No mature tree canopy is present at this exposure area. Sporadic vegetation generally consists of weedy herbaceous species and small woody shrubs. Representative herbaceous species include: goldenrods (*Solidago* spp.), common mugwort *(Artemisia vulgaris)*, thistles (*Cirsium* sp.), annual ragweed (*Ambrosia artemisiifolia*), spotted knapweed *(Centaurea maculosa)*, common mullein *(Verbascum thapsus)*, little bluestem *(Schizachyrium scoparius)*, Queen Anne's lace *(Daucus carota)*, and pokeweed *(Phytolacca americana)*. Shrubs include: quaking aspen *(Populus tremuloides)*, American elm *(Ulmus americana)*, and Eastern cottonwood *(Populus deltoides)*.

While the bases of loose piles of sand and stone may provide burrowing habitat for small mammals, the persistence of this habitat is low due to the transient nature of the piles and apparent frequency of disturbance at the exposure area. No snags, tree cavities, or valuable coarse woody debris are present for wildlife usage and the vegetative species present provide relatively low levels of food for wildlife. No wetlands or vernal pools are present at the exposure area.

The principal pathway for exposure of terrestrial receptors to COPCs in the terrestrial environment is contact with surficial soils. Soil sampling data indicate that PCBs are present in two samples within the building footprint. Given the small size (<1.0 acres) of undeveloped impacted property and the limited vegetated cover (i.e., lack of suitable habitat), the site appears to qualify for exclusion from assessment of risk of harm to terrestrial life under MCP guidance (MassDEP, 1996).

5.1.2 Quaboag River and Wetlands. The second exposure area is the wetland area adjacent to the Quaboag River. This wetland consists of three components. The first component is a narrow wetland swale which lies along the north side of a railroad bed and is comprised of wetland species including: wide-leaf cattail (*Typha latifolia*), purple loosestrife (*Lythrum salicaria*), horsetails (*Equisetum sp.*), silky dogwood (*Cornus amomum*), staghorn sumac (*Rhus typhina*), and several other shrub species. This area provides some food for wildlife (dogwood berries,

etc.) and potential nesting habitat for bird species, although proximity to the active railway may discourage nesting activity.

The second component of the wetland area represents the highest quality wildlife habitat found adjacent to the site. This area is comprised of a mix of shrubs and herbs with: grey birch (*Betula populifolia),* silky dogwood, autumn olive (*Elaeagnus umbellate*), staghorn sumac, Asiatic bittersweet (*Celastrus orbiculatus*) and sporadic Japanese knotweed (*Polygonum cuspidatum).* The forested wetland canopy includes American elm, green ash (*Fraxinus pennsylvanica*), and red maple (*Acer rubrum*). Dead snags with potential nesting cavities are present in this portion of the wetland.

The final component of the wetland area is a palustrine emergent wetland associated with the Quaboag River. Emergent species include: wide-leaf cattail, smartweed (*Polygonum spp.),* woolgrass (*Scirpus cyperinus*), American burreed (*Sparganium americanum*), broadleaf arrowhead (*Sagittaria latifolia)*, buttonbush (*Cephalanthus occidentalis*), and lilies (*Nuphar spp.).* This emergent wetland provides habitat for various amphibians including Green frog (*Rana clamitans*).

Species listed by NHESP are unlikely to inhabit the wetland area adjacent to the site. While no American Bittern were observed the day of the field investigation, the emergent wetland, particularly with its abundance of frogs, could provide valuable habitat for this species. However, given the secretive nature of this species, the frequent disturbances at the site would not likely provide valuable wildlife habitat for the American Bittern. No Long's Bulrush were observed during the field visit, although it is possible that it may be found in the emergent wetland. Since it is a wetland species, it is extremely unlikely that it would be found on or impacted by activity at the site.

The pied-billed grebe typically uses habitat dominated by cattails, reeds, and other vegetation which can provide cover and nesting materials and may be found near rivers, estuaries, or tidal creeks. The Quaboag River and adjacent wetlands may provide usable habitat for the pied-billed

grebe, however the project site does not contain suitable nesting or feeding habitat and the grebe is therefore unlikely to be found on the project site.

The sedge wren occupies drier transitional edges of freshwater marshes, bogs and wet meadows. The upper periphery of emergent wetlands adjacent to the Quaboag River may provide some nesting habitat for the sedge wren. However, it is unlikely that the sedge wren would be found on the project site due to a lack of suitable vegetation, distance from the wetland, and the shy and elusive nature of the species.

Bridle shiners are small minnows that occupy clear water in slack areas of streams and rivers. They are often associated with moderate levels of submerged aquatic vegetation and open areas where they can school. While the Quaboag River may provide habitat for bridle shiners, the project site contains no aquatic habitat.

The blue-spotted salamander requires moist, moderately shaded habitats, favoring northern hardwood/hemlock forests with depressions available for seasonal flooding. Temporarily ponded areas such as vernal pools, especially if containing numerous dead and decaying leaves for cover and overhanging bushes or grass for egg deposition, often provide valuable habitat. While no hardwood/hemlock forests or vernal pools are located close to the site, drainage ditches such as the ditches found adjacent to the railbed may provide some habitat for the blue-spotted salamander reproduction. Adult salamanders spend most of the year beneath leaf litter or underground to a depth of one meter, usually within 500 meters of their breeding pool. As indicated by NHESP in their rare species fact sheet, "there are two critical components in the life history of this species: vernal pool habitat required for reproduction and upland forest habitat required for foraging, hibernation, and other terrestrial and fossorial activities". Since the project site does not contain forested habitat, has undergone various degrees of disturbance, and generally contains dry soils during much of the year, it is unlikely that blue-spotted salamanders would occur on the project site. However, there is a small possibility of encountering transient salamanders during the breeding period, such as during a wet Spring night.

Based on the groundwater flow direction, the river and wetlands are hydrologically downgradient of the site and likely receive groundwater discharge containing COPCs. Though significant dilution of groundwater concentrations is expected upon discharge to the river, this potential migration pathway may have resulted in an impact to surface water in the wetlands where dilution is low. For a surface water exposure scenario, this assessment assumed that 10 percent of groundwater COPC concentrations discharge to pools in the wetland. Exposure to modeled concentrations of metals discharging to the wetland area is being considered as a potential pathway. Potential receptors include invertebrates, amphibians, birds, and mammals. Potential risk of harm to environmental receptors in this fresh water setting was evaluated through comparison of COPC EPCs to Applicable, Available or Analogous Standards or Guidelines.

5.2 EXPOSURE POINT CONCENTRATIONS

In order to evaluate surface water, the Stage I Environmental Screening assumes that concentrations of COPCs in groundwater discharge to the downgradient wetlands. EPCs for the surface water scenario were derived using the 95% UCL COPC groundwater concentration from upgradient site wells (MEW-3, MEW-4, MEW-7, MEW-9, and P-3), and diluting the concentration by a factor of 10. The 10-fold dilution accounts for the dilution/attenuation that would occur prior to discharge. Use of this default dilution factor is consistent with its use in the calculation of MassDEP's GW-3 standards. Groundwater data for the wells listed above were collected in February, May, September, and November 2006 and analyzed for total metals (Table 4).

5.3 BENCHMARK VALUES

Invertebrates potentially occurring on-site are expected to be similar to those used in toxicity tests used to derive screening benchmarks. In addition, this Stage I Environmental Screening assumes that any organisms inhabiting the wetland area will be exposed to COPCs.

Screening criteria for surface water were obtained from Lowest Ambient Water Quality Criteria (LAWQC) (MassDEP, 2006). These benchmark values are considered to be conservative for the protection of aquatic organisms.

5.4 COMPARISON OF CONTAMINANT CONCENTRATIONS TO BENCHMARKS

To assess surface water risk, 95% UCL groundwater concentrations in upgradient monitoring wells were diluted 10-fold and then compared to surface water screening benchmarks. With the exception of lead, all concentrations were below benchmark values. As shown in Table 68, the estimated surface water concentration of lead (1.3 ug/L) exceeds its LAWQC benchmark (0.5 ug/L). The lead criterion (0.5 ug/L) is hardness-dependent and is calculated using a default hardness value of 20 mg/L. Using site-specific groundwater data collected in 2002 (see Phase II report), calcium concentrations in groundwater averaged approximately 50 mg/l. Using EPA guidance for calculating freshwater dissolved metals criteria that are hardness-dependent (US EPA 2007b), the site-specific criteria for lead is approximately 1.0 ug/L. However, the modeled surface water concentration for lead still exceeds the site-specific criterion and therefore, exceeds the LAWQC. Further, the LAWQC for lead was developed for daphnia, which could possibly be found in the wetland area.

6.0 CONCLUSIONS AND RECOMMENDATIONS

A MCP Method 3 Human Health Risk Characterization has been conducted for baseline conditions at the site in accordance with the requirements of 310 CMR 40.0990, using applicable soil and groundwater analytical sampling data. Airborne particulate data were derived from soil data using default MassDEP PM_{10} values for the adolescent trespasser, town worker, construction worker, on-site worker, and residential (adult and child) exposure scenarios. Surface water exposure point concentrations for the downgradient wetland were derived from groundwater data using a default 10-fold dilution factor. Indoor and outdoor atmospheric data were derived from soil data using vapor migration and air dispersion/dilution models.

Under current site activities and uses, potential exposures to COPCs in soil pose no significant risk of harm to current town workers or trespassers, and COPCs in surface water pose no significant risk of harm to current adolescent recreational users. There are no current direct exposure pathways completed for groundwater.

Under future foreseeable site activities and uses, potential exposures to COPCs in groundwater and surface water pose no significant risk of harm to future construction workers and future recreational users, respectively. In addition, potential exposures to COPCs in soil pose no significant risk of harm to future trespassers, on-site workers, construction workers, or adult residents across the site. The evaluation of future indoor and outdoor air pathways also indicates no significant risk of harm to future on-site workers, construction workers, or residents. Significant risk of harm is posed to future child residents, exposed to soil throughout the site, primarily attributable to the presence of lead in soil. The evaluation also indicates a future risk of harm to child recreational users exposed to soil should the site be developed as a park.

Risk of harm to safety is significant under both current and future foreseeable site conditions due to the presence of visible physical hazards (e.g., unstable slopes, glass, rusted waste). No chemical hazards (e.g., corrosive, flammable/ignitable, reactive materials) are present at the site.

There is currently no condition of unilateral restrictions on the uses of the abutting property, negative impacts on residences hydraulically downgradient of the site, or reports of significant degradation of public or private drinking water resources as a result of the COPC release. In addition, maximum COPC soil and groundwater concentrations do not exceeded their respective UCLs.

Using a Stage I Environmental Screening, risk of harm to the environment was assessed for two independent ecological units: terrestrial and wetland exposure areas. Although PCBs were present in soil samples, given the small size (<1.0 acres) of the site, the site appears to qualify for exclusion from assessment of risk of harm to terrestrial life. However, the modeled surface water concentration of lead exceeds its LAWQC. Therefore, there is evidence that COPC concentrations in

surface water, via groundwater discharge, may pose a risk of harm to aquatic habitat in the wetland area.

Based on these findings, site conditions are considered to pose significant risk of harm to human health, safety, and the environment under current and/or future foreseeable site activities and uses. To address this risk of harm to human health under future foreseeable site activities and uses and to achieve a condition of no significant risk, implementation of an Activity and Use Limitation (AUL) pursuant to 310 CMR 40.1012 is indicated. Further study and/or remedial actions are indicated to address the risk of harm to safety and the environment.

7.0 REFERENCES

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TABLE 1
SUMMARY STATISTICS FOR SURFACE SOILS
FORMER BROOKFIELD MILL SITE

Analytes	Frequency of Detection	Minimum Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Soil Background (mg/kg)	COPC? Y/N[1]	95% UCL Concentration (mg/kg)	EPC[2]
C9-C12 Aliphatics	1 / 7	12	12	NA	Y	9.9	9.9
C9-C18 Aliphatics	3 / 6	4.2	53	NA	Y	95	53
C19-C36 Aliphatics	6 / 6	12	530	NA	Y	459	459
C11-C22 Aromatics	3 / 6	22	85	NA	Y	80	80
2-Methylnaphthalene	1 / 6	0.85	0.85	0.5	Y	0.56	0.56
Benzo(b)fluoranthene	2 / 6	0.92	1.1	2	N	NA	NA
Dibenz(a,h)anthracene	2 / 6	0.6	0.71	0.5	Y	0.58	0.58
Fluoranthene	2 / 6	0.59	1.1	4	N	NA	NA
Indeno(1,2,3-cd)pyrene	2 / 6	0.6	0.71	1	N	NA	NA
Phenanthrene	1 / 6	1.1	1.1	3	N	NA	NA
Pyrene	2 / 6	0.65	1.1	4	N	NA	NA
Aroclor-1260	2 / 4	0.11	0.14	NA	Y	0.14	0.14
Aluminum	10 / 10	4170	11700	10000	Y	10545	10545
Antimony	1 / 25	2.2	2.2	1	Y	0.78	0.78
Arsenic	20 / 25	2	8.6	20	N	NA	NA
Barium	25 / 25	13.8	2230	50	Y	468	468
Beryllium	5 / 25	0.11	1.4	0.4	Y	0.44	0.44
Cadmium	15 / 25	0.21	1.7	2	N	NA	NA
Calcium	10 / 10	277	29900	NA	N[3]	NA	NA
Chromium	25 / 25	3.3	71	30	Y	31	31
Cobalt	10 / 10	1.3	12.2	4	Y	6.6	6.6
Copper	21 / 25	3	4520	40	Y	2164	2164
Iron	10 / 10	4200	63900	20000	Y	37252	37252
Lead	25 / 25	3.5	1300	100	Y	406	406
Magnesium	10 / 10	270	3660	5000	N	NA	NA
Manganese	10 / 10	30.9	343	300	Y	226	226
Mercury	17 / 25	0.044	0.49	0.3	Y	0.19	0.19
Nickel	20 / 25	2.3	28.5	20	Y	9.8	9.8
Potassium	10 / 10	217	3160	NA	N[3]	NA	NA
Selenium	4 / 25	0.53	1.3	0.5	Y	7.4	1.3
Silver	3 / 25	0.96	1.2	0.6	Y	3.1	1.2
Sodium	9 / 10	78.6	2900	NA	N[3]	NA	NA
Thallium	1 / 25	1.3	1.3	0.6	Y	1.9	1.3
Vanadium	25 / 25	6.3	43.2	30	Y	26	26
Zinc	22 / 25	6.8	1600	100	Y	359	359

1. Analytes excluded as COPCs when maximum detected concentration is less than MassDEP background concentration (MassDEP, 2006).
2. 95% UCL concentration selected as EPC unless greater than maximum, in which case maximum is selected.
3. Essential nutrient

EPC - Exposure Point Concentration
NA - Not applicable or not available
COPC - Chemical of Potential Concern
UCL - Upper Confidence Limit

TABLE 2
SUMMARY STATISTICS FOR SURFACE AND SUBSURFACE SOILS
FORMER BROOKFIELD MILL SITE

Analytes	Frequency of Detection	Minimum Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)	Soil Background (mg/kg)	COPC? Y/N[1]	95% UCL Concentration (mg/kg)	EPC[2]
C9-C12 Aliphatics	1 / 12	12	12	NA	Y	5.1	5.1
C9-C18 Aliphatics	4 / 11	3.675	53	NA	Y	53	53
C19-C36 Aliphatics	8 / 11	12	530	NA	Y	245	245
C11-C22 Aromatics	5 / 11	12	85	NA	Y	91	85
2-Methylnaphthalene	1 / 11	0.85	0.85	0.5	Y	0.43	0.43
Benzo(a)anthracene	1 / 11	0.495	0.495	2	N	NA	NA
Benzo(a)pyrene	1 / 11	0.5	0.5	2	N	NA	NA
Benzo(b)fluoranthene	4 / 11	0.92	1.25	2	N	NA	NA
Dibenz(a,h)anthracene	3 / 11	0.6	0.82	0.5	Y	0.52	0.52
Fluoranthene	3 / 11	0.59	1.4	4	N	NA	NA
Indeno(1,2,3-cd)pyrene	3 / 11	0.6	0.82	1	N	NA	NA
Phenanthrene	2 / 11	1.1	1.5	3	N	NA	NA
Pyrene	3 / 11	0.65	1.35	4	N	NA	NA
Aroclor-1260	3 / 6	0.11	0.14	NA	Y	0.12	0.12
Aluminum	19 / 19	4170	17825	10000	Y	10730	10730
Antimony	3 / 49	2.2	2.6	1	Y	1.0	1.0
Arsenic	38 / 49	1.2	8.9	20	N	NA	NA
Barium	49 / 49	13.8	2800	50	Y	1007	1007
Beryllium	10 / 49	0.11	1.4	0.4	Y	0.32	0.32
Cadmium	27 / 49	0.21	1.7	2	N	NA	NA
Calcium	19 / 19	277	29900	NA	N[3]	NA	NA
Chromium	49 / 49	3.3	71	30	Y	22	22
Cobalt	19 / 19	1.3	33.3	4	Y	9.2	9.2
Copper	42 / 49	3	4520	40	Y	1431	1431
Iron	19 / 19	4200	63900	20000	Y	33363	33363
Lead	45 / 49	2.25	1300	100	Y	562	562
Magnesium	19 / 19	270	3660	5000	N	NA	NA
Manganese	19 / 19	30.9	367	300	Y	238	238
Mercury	24 / 49	0.044	2.2	0.3	Y	0.60	0.60
Nickel	42 / 49	2.3	47	20	Y	16	16
Potassium	19 / 19	217	3390	NA	N[3]	NA	NA
Selenium	6 / 49	0.53	1.3	0.5	Y	5.3	1.3
Silver	5 / 49	0.96	2.07	0.6	Y	2.5	2.07
Sodium	18 / 19	78.6	2900	NA	N[3]	NA	NA
Thallium	2 / 49	1.1	1.3	0.6	Y	1.6	1.3
Vanadium	48 / 49	6.3	69.5	30	Y	28	28
Zinc	44 / 49	6.8	1600	100	Y	637	637

1. Analytes excluded as COPCs when maximum detected concentration is less than MassDEP background concentration (MassDEP, 2006).
2. 95% UCL concentration selected as EPC unless greater than maximum, in which case maximum is selected.
3. Essential nutrient

EPC - Exposure Point Concentration
NA - Not applicable or not available
COPC - Chemical of Potential Concern
UCL - Upper Confidence Limit

TABLE 3
SUMMARY STATISTICS FOR 2002 GROUNDWATER DATA
FORMER BROOKFIELD MILL SITE

Analytes	Frequency of Detection	Minimum Detected Concentration	Maximum Detected Concentration	Maximum Upgradient Groundwater Concentration		MCP Groundwater Standards	
						GW-2	GW-3
VOCs (ug/L)							
Acetone	1 / 3	9.6	9.6	50		50000	50000
Methyl-t-butyl ether (MTBE)	1 / 3	1.1	1.1	0.5	U	50000	50000
Metals (ug/L)							
Aluminum	1 / 3	595	595	49.4	U	NA	NA
Barium	3 / 3	20.7	85	20.3		NA	50000
Calcium	3 / 3	14100	134000	16600		NA	NA
Cobalt	1 / 3	15.5	15.5	5.6	U	NA	NA
Iron	1 / 3	617	617	416		NA	NA
Magnesium	3 / 3	3350	17200	4130		NA	NA
Manganese	3 / 3	140	381.5	672		NA	NA
Potassium	3 / 3	2320	28800	3720		NA	NA
Sodium	3 / 3	29100	138000	10900		NA	NA
Zinc	1 / 3	3.9	3.9	5.6		NA	900

NA - Not applicable or not available
U - Not Detected; concentration shown is the detection limit

TABLE 4
SUMMARY STATISTICS FOR 2006 GROUNDWATER DATA
FORMER BROOKFIELD MILL SITE

Analytes	Frequency of Detection	Minimum Detected Concentration	Maximum Detected Concentration	Groundwater Background	COPC? Y/N[1]	95% UCL Concentration	Ground-water EPC[2]	Surface Water EPC[3]
Metals (ug/L)								
Lead	10 / 20	6.0	18	8.8	Y	13	13	1.3
Zinc	6 / 20	53	195	NA	Y	126	126	12.6

1. Analytes excluded as COPCs when maximum detected concentration is less than MassDEP background concentration (MassDEP, 2006).
2. 95% UCL concentration selected as EPC unless greater than maximum, in which case maximum is selected.
3. A 10-fold dilution has been applied to the groundwater EPC to estimate the surface water discharge EPC.

EPC - Exposure Point Concentration
NA - Not applicable or not available
COPC - Chemical of Potential Concern
UCL - Upper Confidence Limit

TABLE 5
SOIL TO INDOOR AIR - MAXIMUM SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Soil EPC	Soil Temp.	Soil Temp.	Henry's Law Constant at ref. temp.	Henry's Law Reference Temp.	Normal Boiling Point	Enthalpy of vaporization at T_S	Critical Temp.	constant	Enthalpy of vaporization at T_S	Gas Constant	Henry's Law Constant at T_S	Gas Constant	Henry's Law Constant
	C_R	T_S	T'_S	H_R	T_R	T_B	$\Delta H_{v,B}$	T_C	n	$\Delta H_{v,TS}$	R_c	H_{TS}	R	H'_{TS}
Units:	µg/kg	°C	K	atm-m^3/mol	K	K	cal/mol	K	unitless	cal/mol	cal/mol-K	atm-m^3/mol	m^3-atm/mol-K	unitless
Formula:	**Input**	(10 for screening)	(T_S + 273.15)	lookup	(lookup+273.15)	lookup	lookup	lookup	(Note 7)	(Note 8)		(Note 9)		H_{TS} / (R * T'_S)
Analyte														
C9-C12 Aliphatics	**1.20E+04**	1.00E+01	2.83E+02	1.56E+00	2.98E+02	NA	NA	NA	NA	NA	1.99E+00	1.56E+00	8.21E-05	6.71E+01
C9-C18 Aliphatics	**5.30E+04**	1.00E+01	2.83E+02	1.66E+00	2.98E+02	NA	NA	NA	NA	NA	1.99E+00	1.66E+00	8.21E-05	7.13E+01
C11-C22 Aromatics	**8.50E+04**	1.00E+01	2.83E+02	7.20E-04	2.98E+02	NA	NA	NA	NA	NA	1.99E+00	7.20E-04	8.21E-05	3.10E-02
2-Methylnaphthalene	**8.50E+02**	1.00E+01	2.83E+02	5.18E-04	2.98E+02	5.14E+02	1.08E+04	7.61E+02	3.84E-01	1.40E+04	1.99E+00	1.49E-04	8.21E-05	6.40E-03
Phenanthrene	**1.50E+03**	1.00E+01	2.83E+02	4.23E-05	2.98E+02	6.13E+02	1.31E+04	8.69E+02	4.06E-01	1.84E+04	1.99E+00	8.16E-06	8.21E-05	3.51E-04

TABLE 5 (continued)
SOIL TO INDOOR AIR - MAXIMUM SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Conversion Factor µg/kg to g/g	SCS soil type in vadose zone	Vadose zone soil dry bulk density	Vadose zone soil water-filled porosity	Organic carbon partition coefficient	Vadose zone organic carbon fraction	Soil-water partition coefficient	Vadose zone soil total porosity	Vadose zone soil air-filled porosity	Conversion Factor g/cm^3 to $\mu g/m^3$	Source Vapor Conc.
	Conv01	ST_v	ρ_b	$\theta_{w,v}$	K_{oc}	$f_{oc,v}$	K_d	n_v	$\theta_{a,v}$	Conv03	C_{source}
Units:	µg/kg / g/g	unitless	g/cm^3	cm^3/cm^3	cm^3/g	unitless	cm^3/g	cm^3/cm^3	cm^3/cm^3	g/cm^3 / $\mu g/m^3$	$\mu g/m^3$
Formula:		(Note 11)	lookup	lookup	lookup	(0.002 for screening)	$K_{oc} * f_{oc}$	lookup	$n_v - \theta_{w,v}$		(Note 21)
Analyte											
C9-C12 Aliphatics	1.00E-09	SCL	1.63E+00	1.46E-01	1.50E+05	2.00E-03	3.00E+02	3.84E-01	2.38E-01	1.00E+12	2.60E+06
C9-C18 Aliphatics	1.00E-09	SCL	1.63E+00	1.46E-01	6.80E+05	2.00E-03	1.36E+03	3.84E-01	2.38E-01	1.00E+12	2.76E+06
C11-C22 Aromatics	1.00E-09	SCL	1.63E+00	1.46E-01	5.01E+03	2.00E-03	1.00E+01	3.84E-01	2.38E-01	1.00E+12	2.60E+05
2-Methylnaphthalene	1.00E-09	SCL	1.63E+00	1.46E-01	2.50E+03	2.00E-03	5.00E+00	3.84E-01	2.38E-01	1.00E+12	1.07E+03
Phenanthrene	1.00E-09	SCL	1.63E+00	1.46E-01	1.40E+04	2.00E-03	2.80E+01	3.84E-01	2.38E-01	1.00E+12	1.88E+01

TABLE 5 (continued)
SOIL TO INDOOR AIR - MAXIMUM SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Depth below grade to bottom of enclosed space	Depth below grade to contamination	Source Building Separation	Diffusivity in air	Diffusivity in water	Vadose zone Effective Diffusion Coeff.	Total Overall Effective Diffusion Coeff.	Area of Enclosed Space Below Grade	Building Ventilation Rate	Pressure Diff. between soil & enclosed space	Vadose zone soil saturated hydraulic conductivity
	L_F	L_t	L_T	D_a	D_w	D_v^{eff}	D_T^{eff}	A_B	$Q_{building}$	ΔP	$K_{s,v}$
Units:	cm	cm	cm	cm^2/s	cm^2/s	cm^2/s	cm^2/s	cm^2	cm^3/s	$g/cm\text{-}s^2$	cm/hr
Formula:	(15 or 200 for screening)	(400 for screening)	$L_t - L_F$	lookup	lookup	(Note 13)	(Note 4)	(Note 2)	(Note 2a)	(40 for screening)	lookup
Analyte											
C9-C12 Aliphatics	2.00E+02	4.00E+02	2.00E+02	7.00E-02	1.00E-06	3.99E-03	3.99E-03	1.80E+06	2.54E+04	4.00E+01	5.50E-01
C9-C18 Aliphatics	2.00E+02	4.00E+02	2.00E+02	7.00E-02	5.00E-06	3.99E-03	3.99E-03	1.80E+06	2.54E+04	4.00E+01	5.50E-01
C11-C22 Aromatics	2.00E+02	4.00E+02	2.00E+02	6.00E-02	1.00E-06	3.42E-03	3.42E-03	1.80E+06	2.54E+04	4.00E+01	5.50E-01
2-Methylnaphthalene	2.00E+02	4.00E+02	2.00E+02	6.29E-02	7.20E-06	3.59E-03	3.59E-03	1.80E+06	2.54E+04	4.00E+01	5.50E-01
Phenanthrene	2.00E+02	4.00E+02	2.00E+02	3.33E-02	7.47E-06	2.13E-03	2.13E-03	1.80E+06	2.54E+04	4.00E+01	5.50E-01

TABLE 5 (continued)
SOIL TO INDOOR AIR - MAXIMUM SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Conversion Factor hr to s	Viscosity of water at 10°C	Viscosity of water at system temp.	Density of water	Acceleration due to gravity	Vadose zone soil intrinsic permeability	Vadose zone residual soil water content	Vadose zone effective total fluid saturation	Vadose zone van Genuchten shape parameter	Vadose zone soil relative air permeability	Vadose zone soil effective vapor permeability
Units:	Conv02	μ_{w-10}	μ_w	ρ_w	g	$k_{i,v}$	$\theta_{r,v}$	S_{te}	M_v	k_{rg}	k_v
Formula:	s/hr	g/cm-s	g/cm-s	g/cm^3	cm/s^2	cm^2	cm^3/cm^3	unitless	unitless	unitless	cm^2
			(Note 16)	(0.999 for screening)		(Note 17)	lookup	(Note 18)	lookup	(Note 19)	(Note 20)
Analyte											
C9-C12 Aliphatics	3.60E+03	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09
C9-C18 Aliphatics	3.60E+03	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09
C11-C22 Aromatics	3.60E+03	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09
2-Methylnaphthalene	3.60E+03	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09
Phenanthrene	3.60E+03	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09

TABLE 5 (continued)
SOIL TO INDOOR AIR - MAXIMUM SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Floor-wall seam perimeter	Vapor viscosity at avg. soil temp.	Crack depth below grade	Total area of cracks	Crack-to-total area ratio	Equivalent crack radius	Avg. Vapor Flow Rate Into Bldg.	Foundation or Slab Thickness	Crack Effective Diffusion Coeff.	Infinite Source Indoor Attenuation Coeff.	Infinite Source Bldg. Conc.
	X_{crack}	μ_{TS}	Z_{crack}	A_{crack}	η	r_{crack}	Q_{soil}	L_{crack}	D^{crack}	α	$C_{building}$
Units:	cm	g/cm-s	cm	cm^2	unitless	cm	cm^3/s	cm	cm^2/s	unitless	$\mu g/m^3$
Formula:	(4000 for screening)	0.00018*(T's/298.15)^0.5	(= L_F for screening)	(400 for screening)	A_{crack}/A_B	$\eta(A_B/X_{crack})$	(Note 5)	(10 for screening)	(Note 1)	(Note 6)	$C_{source} * \alpha$
Analyte											
C9-C12 Aliphatics	4.00E+03	1.75E-04	2.00E+02	4.00E+02	2.22E-04	1.00E-01	1.21E+00	1.00E+01	3.99E-03	4.61E-05	1.20E+02
C9-C18 Aliphatics	4.00E+03	1.75E-04	2.00E+02	4.00E+02	2.22E-04	1.00E-01	1.21E+00	1.00E+01	3.99E-03	4.61E-05	1.27E+02
C11-C22 Aromatics	4.00E+03	1.75E-04	2.00E+02	4.00E+02	2.22E-04	1.00E-01	1.21E+00	1.00E+01	3.42E-03	4.58E-05	1.19E+01
2-Methylnaphthalene	4.00E+03	1.75E-04	2.00E+02	4.00E+02	2.22E-04	1.00E-01	1.21E+00	1.00E+01	3.59E-03	4.59E-05	4.91E-02
Phenanthrene	4.00E+03	1.75E-04	2.00E+02	4.00E+02	2.22E-04	1.00E-01	1.21E+00	1.00E+01	2.13E-03	4.48E-05	8.40E-04

TABLE 5 (continued)
SOIL TO INDOOR AIR - MAXIMUM SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

Notes:

Reference: *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings*, USEPA, June 19, 2003.

(1) Assumed equivalent to D_i^{eff} of soil layer i in contact with the floor

(2) For screening, A_B = 1,000,000 cm^2 for L_F <= 15 cm and A_B = 1,800,000 cm^2 for LF > 15 cm

(2a) For screening, $Q_{building}$ = 25,417 cm^3/s for L_F <= 15 cm and $Q_{building}$ = 16,944 cm^3/s for LF > 15 cm

(3) Purposely left blank

(4) $D_T^{eff} = L_T / (L_T / D_v^{eff})$

(5) $Q_{soil} = (2*\pi*\Delta P*k_v*X_{crack}) / (\mu_{TS}*\ln(2*Z_{crack}/r_{crack}))$

(6) $\alpha = [(D_T^{eff}*A_B/(Q_{building}*L_T))*EXP(Q_{soil}*L_{crack}/(D^{crack}*A_{crack}))]/[EXP(Q_{soil}*L_{crack}/(D^{crack}*A_{crack}))+(D_T^{eff}*A_B/(Q_{building}*L_T))+(D_T^{eff}*A_B/(Q_{soil}*L_T))*(EXP(Q_{soil}*L_{crack}/(D^{crack}*A_{crack}))-1)]$

(7) A function of the ratio T_B/T_C:

T_B/T_C	n
<0.57	0.30
0.57-0.71	$0.74(T_B/T_C)-0.116$
>0.71	0.41

If values are not available for calculation, result is NA.

(8) $\Delta H_{v,TS} = \Delta H_{v,B}*[(1-T_S/T_C)/(1-T_B/T_C)]^n$; if values are not available for calculation, result is NA.

(9) $H_{TS} = EXP[-\Delta H_{v,TS}/R_c*(1/T_S-1/T_R)]*H_R$; if values are not available for calculation, result assumed to be H_R

(10) Purposely left blank

(11) Refer to 12 SCS soil types - if no site-specific information is available, use SCL for screening.

(12) Purposely left blank

(13) $D_v^{eff} = D_a*(\theta_{a,v}^{3.33}/n_v^2)+(D_w/H'_{TS})(\theta_{w,v}^{3.33}/n_v^2)$

(14) Purposely left blank

(15) Purposely left blank

(16) $\mu_w = \mu_{w-10} * (T'_S / 283.15)^{0.5}$

(17) $k_{i,v} = K_{s,v} * 1/Conv02 * \mu_w / (\rho_w * g)$

(18) $S_{te} = (\theta_{w,v} - \theta_{r,v}) / (n_v - \theta_{r,v})$

(19) $k_{rg} = (1 - S_{te})^{0.5} * (1-S_{te}^{1/Mv})^{2Mv}$

(20) $k_v = k_{i,v} * k_{rg}$; note that the model is very sensitive to this parameter and if site-specific values are available, they should be used.

(21) $C_{source} = H'_{TS} * C_R * Conv01 * \rho_b / (\theta_{w,v} + K_d * \rho_b + H'_{TS} * \theta_{a,v}) * Conv02$

TABLE 6. SELECTION OF INDOOR AIR COPCs
FORMER BROOKFIELD MILL SITE

	Air Concentrations (ug/m^3)		
	Soil to Indoor Air	**Indoor Air Background**	**COPC? Y/N[1]**
Analyte			
C9-C12 Aliphatics	1.2E+02	9.0E+01	Y
C9-C18 Aliphatics	1.3E+02	1.0E+02	Y
C11-C22 Aromatics	1.2E+01	5.0E+01	N
2-Methylnaphthalene	4.9E-02	1.7E+00	N
Phenanthrene	8.4E-04	NA	Y

1. Analytes excluded as COPCs when maximum detected concentration is less than MassDEP background concentration (MassDEP, 2006).

NA - Not Available

COPC - Chemical of Potential Concern

TABLE 7
SOIL TO OUTDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Soil EPC	Soil Temp.	Soil Temp.	Henry's Law Constant at ref. temp.	Henry's Law Reference Temp.	Normal Boiling Point	Enthalpy of vaporization at T_S	Critical Temp.	constant	Enthalpy of vaporization at T_S	Gas Constant	Henry's Law Constant at T_S	Gas Constant	Henry's Law Constant
	C_R	T_S	T'_S	H_R	T_R	T_B	$\Delta H_{v,B}$	T_C	n	$\Delta H_{v,TS}$	R_c	H_{TS}	R	H'_{TS}
Units:	µg/kg	°C	K	atm-m^3/mol	K	K	cal/mol	K	unitless	cal/mol	cal/mol-K	atm-m^3/mol	m^3-atm/mol-K	unitless
Formula:	**Input**	(10 for screening)	(T_S + 273.15)	lookup	(lookup+273.15)	lookup	lookup	lookup	(Note 7)	(Note 8)		(Note 9)		H_{TS} / (R * T'_S)
Analyte														
C9-C12 Aliphatics	**5.08E+03**	1.00E+01	2.83E+02	1.56E+00	2.98E+02	NA	NA	NA	NA	NA	1.99E+00	1.56E+00	8.21E-05	6.71E+01
C9-C18 Aliphatics	**5.29E+04**	1.00E+01	2.83E+02	1.66E+00	2.98E+02	NA	NA	NA	NA	NA	1.99E+00	1.66E+00	8.21E-05	7.13E+01
C11-C22 Aromatics	**8.50E+04**	1.00E+01	2.83E+02	7.20E-04	2.98E+02	NA	NA	NA	NA	NA	1.99E+00	7.20E-04	8.21E-05	3.10E-02
2-Methylnaphthalene	**4.29E+02**	1.00E+01	2.83E+02	5.18E-04	2.98E+02	5.14E+02	1.08E+04	7.61E+02	3.84E-01	1.40E+04	1.99E+00	1.49E-04	8.21E-05	6.40E-03
Phenanthrene	**1.03E+03**	1.00E+01	2.83E+02	4.23E-05	2.98E+02	6.13E+02	1.31E+04	8.69E+02	4.06E-01	1.84E+04	1.99E+00	8.16E-06	8.21E-05	3.51E-04

TABLE 7 (continued)
SOIL TO OUTDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Conversion Factor µg/kg to g/g	SCS soil type in vadose zone	Vadose zone soil dry bulk density	Vadose zone soil water-filled porosity	Organic carbon partition coefficient	Vadose zone organic carbon fraction	Soil-water partition coefficient	Vadose zone soil total porosity	Vadose zone soil air-filled porosity	Conversion Factor g/cm^3 to $\mu g/m^3$	Source Vapor Conc.
	Conv01	ST_v	ρ_b	$\theta_{w,v}$	K_{oc}	$f_{oc,v}$	K_d	n_v	$\theta_{a,v}$	Conv03	C_{source}
Units:	µg/kg / g/g	unitless	g/cm^3	cm^3/cm^3	cm^3/g	unitless	cm^3/g	cm^3/cm^3	cm^3/cm^3	g/cm^3 / $\mu g/m^3$	$\mu g/m^3$
Formula:		(Note 11)	lookup	lookup	lookup	(0.002 for screening)	$K_{oc} * f_{oc}$	lookup	$n_v - \theta_{w,v}$		(Note 21)
Analyte											
C9-C12 Aliphatics	1.00E-09	SCL	1.63E+00	1.46E-01	1.50E+05	2.00E-03	3.00E+02	3.84E-01	2.38E-01	1.00E+12	1.10E+06
C9-C18 Aliphatics	1.00E-09	SCL	1.63E+00	1.46E-01	6.80E+05	2.00E-03	1.36E+03	3.84E-01	2.38E-01	1.00E+12	2.75E+06
C11-C22 Aromatics	1.00E-09	SCL	1.63E+00	1.46E-01	5.01E+03	2.00E-03	1.00E+01	3.84E-01	2.38E-01	1.00E+12	2.60E+05
2-Methylnaphthalene	1.00E-09	SCL	1.63E+00	1.46E-01	2.50E+03	2.00E-03	5.00E+00	3.84E-01	2.38E-01	1.00E+12	5.40E+02
Phenanthrene	1.00E-09	SCL	1.63E+00	1.46E-01	1.40E+04	2.00E-03	2.80E+01	3.84E-01	2.38E-01	1.00E+12	1.28E+01

TABLE 7 (continued)
SOIL TO OUTDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Depth below grade to bottom of trench	Depth below grade to contamination	Source Trench Separation	Diffusivity in air	Diffusivity in water	Vadose zone Effective Diffusion Coeff.	Total Overall Effective Diffusion Coeff.	Area of Trench Below Grade	Trench Ventilation Rate	Pressure Diff. between soil & enclosed space	Vadose zone soil saturated hydraulic conductivity	Conversion Factor hr to s
	L_F	L_t	L_T	D_a	D_w	D_v^{eff}	D_T^{eff}	A_B	Q_{trench}	ΔP	$K_{s,v}$	Conv02
Units:	cm	cm	cm	cm^2/s	cm^2/s	cm^2/s	cm^2/s	cm^2	cm^3/s	$g/cm\text{-}s^2$	cm/hr	s/hr
Formula:	(120 (4') for screening)	(400 for screening)	$L_t - L_F$	lookup	lookup	(Note 13)	(Note 4)	(Note 2)	(Note 22)	(40 for screening)	lookup	
Analyte												
C9-C12 Aliphatics	1.20E+02	4.00E+02	2.80E+02	7.00E-02	1.00E-06	3.99E-03	3.99E-03	3.29E+05	1.70E+05	4.00E+01	5.50E-01	3.60E+03
C9-C18 Aliphatics	1.20E+02	4.00E+02	2.80E+02	7.00E-02	5.00E-06	3.99E-03	3.99E-03	3.29E+05	1.70E+05	4.00E+01	5.50E-01	3.60E+03
C11-C22 Aromatics	1.20E+02	4.00E+02	2.80E+02	6.00E-02	1.00E-06	3.42E-03	3.42E-03	3.29E+05	1.70E+05	4.00E+01	5.50E-01	3.60E+03
2-Methylnaphthalene	1.20E+02	4.00E+02	2.80E+02	6.29E-02	7.20E-06	3.59E-03	3.59E-03	3.29E+05	1.70E+05	4.00E+01	5.50E-01	3.60E+03
Phenanthrene	1.20E+02	4.00E+02	2.80E+02	3.33E-02	7.47E-06	2.13E-03	2.13E-03	3.29E+05	1.70E+05	4.00E+01	5.50E-01	3.60E+03

TABLE 7 (continued)
SOIL TO OUTDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Viscosity of water at 10°C	Viscosity of water at system temp.	Density of water	Acceleration due to gravity	Vadose zone soil intrinsic permeability	Vadose zone residual soil water content	Vadose zone effective total fluid saturation	Vadose zone van Genuchten shape parameter	Vadose zone soil relative air permeability	Vadose zone soil effective vapor permeability	Thickness of soil between soilgas & trench
	μ_{w-10}	μ_w	ρ_w	g	$k_{i,v}$	$\theta_{r,v}$	S_{te}	M_v	k_{rg}	k_v	L_{soil}
Units:	g/cm-s	g/cm-s	g/cm^3	cm/s^2	cm^2	cm^3/cm^3	unitless	unitless	unitless	cm^2	cm
Formula:		(Note 16)	(0.999 for screening)		(Note 17)	lookup	(Note 18)	lookup	(Note 19)	(Note 20)	(1 for screening)
Analyte											
C9-C12 Aliphatics	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09	1.00E+00
C9-C18 Aliphatics	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09	1.00E+00
C11-C22 Aromatics	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09	1.00E+00
2-Methylnaphthalene	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09	1.00E+00
Phenanthrene	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09	1.00E+00

TABLE 7 (continued)
SOIL TO OUTDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Vapor viscosity at avg. soil temp.	Avg. Vapor Flow Rate Into trench	Infinite Source Attenuation Coeff.	Infinite Source Trench Conc.
	μ_{TS}	Q_{soil}	α	C_{trench}
Units:	g/cm-s	cm^3/s	unitless	$\mu g/m^3$
Formula:	0.00018*(T'$_S$/298.15)^0.5	(Note 5)	(Note 6)	$C_{source} * \alpha$
Analyte				
C9-C12 Aliphatics	1.75E-04	3.99E-04	2.35E-09	2.59E-03
C9-C18 Aliphatics	1.75E-04	3.99E-04	2.35E-09	6.46E-03
C11-C22 Aromatics	1.75E-04	3.99E-04	2.35E-09	6.12E-04
2-Methylnaphthalene	1.75E-04	3.99E-04	2.35E-09	1.27E-06
Phenanthrene	1.75E-04	3.99E-04	2.35E-09	3.01E-08

TABLE 7 (continued)
SOIL TO OUTDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

Notes:

Reference: *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings*, USEPA, June 19, 2003.

(1) Purposely left blank

(2) For screening, assume a trench 4 ft deep, 3 ft wide, and 30 ft long.

(3) Purposely left blank

(4) $D_T^{eff} = L_T / (L_T / D_v^{eff})$

(5) $Q_{soil} = \Delta P * k_v * L_{soil}) / \mu_{TS}$; not from above reference

(6) $\alpha = [D_T^{eff} * A_B/(Q_{trench} * L_T)]/[(D_T^{eff} * A_B/(Q_{soil} * L_T))+1]$; assumes no resistance (Peclet number is infinite)

(7) A function of the ratio T_B/T_C:

T_B/T_C	n
<0.57	0.30
0.57-0.71	$0.74(T_B/T_C)-0.116$
>0.71	0.41

If values are not available for calculation, result is NA.

(8) $\Delta H_{v,TS} = \Delta H_{v,B} * [(1-T_S/T_C)/(1-T_B/T_C)]^n$; if values are not available for calculation, result is NA.

(9) $H_{TS} = EXP[-\Delta H_{v,TS}/R_c * (1/T_S - 1/T_R)] * H_R$; if values are not available for calculation, result assumed to be H_R

(10) Purposely left blank

(11) Refer to 12 SCS soil types - if no site-specific information is available, use SCL for screening.

(12) Purposely left blank

(13) $D_v^{eff} = D_a * (\theta_{a,v}^{3.33}/n_v^2) + (D_w/H'_{TS})(\theta_{w,v}^{3.33}/n_v^2)$

(14) Purposely left blank

(15) Purposely left blank

(16) $\mu_w = \mu_{w,10} * (T'_S / 283.15)^{0.5}$

(17) $k_{i,v} = K_{s,v} * 1/Conv02 * \mu_w / (\rho_w * g)$

(18) $S_{te} = (\theta_{w,v} - \theta_{r,v}) / (n_v - \theta_{r,v})$

(19) $k_{rg} = (1 - S_{te})^{0.5} * (1 - S_{te}^{1/Mv})^{2Mv}$

(20) $k_v = k_{i,v} * k_{rg}$; note that the model is very sensitive to this parameter and if site-specific values are available, they should be used.

(21) $C_{source} = H'_{TS} * C_R * Conv01 * \rho_b / (\theta_{w,v} + K_d * \rho_b + H'_{TS} * \theta_{a,v}) * Conv02$

(22) For screening, assume a trench 4 ft deep, 3 ft wide, 30 ft long and an air exchange rate of 60/hr. The air exchange rate is based on the assumption that the wind speed in the trench is a small fraction of the ground wind speed and that it could take up to 1 minute for a contaminant to be cleared from the trench air space.

TABLE 8
SOIL TO INDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Soil EPC	Soil Temp.	Soil Temp.	Henry's Law Constant at ref. temp.	Henry's Law Reference Temp.	Normal Boiling Point	Enthalpy of vaporization at T_S	Critical Temp.	constant	Enthalpy of vaporization at T_S	Gas Constant	Henry's Law Constant at T_S	Gas Constant	Henry's Law Constant
	C_R	T_S	T'_S	H_R	T_R	T_B	$\Delta H_{v,B}$	T_C	n	$\Delta H_{v,TS}$	R_c	H_{TS}	R	H'_{TS}
Units:	µg/kg	°C	K	atm-m^3/mol	K	K	cal/mol	K	unitless	cal/mol	cal/mol-K	atm-m^3/mol	m^3-atm/mol-K	unitless
Formula:	**Input**	(10 for screening)	(T_S+ 273.15)	lookup	(lookup+273.15)	lookup	lookup	lookup	(Note 7)	(Note 8)		(Note 9)		H_{TS} / (R * T'_S)
Analyte														
C9-C12 Aliphatics	**5.08E+03**	1.00E+01	2.83E+02	1.56E+00	2.98E+02	NA	NA	NA	NA	NA	1.99E+00	1.56E+00	8.21E-05	6.71E+01
C9-C18 Aliphatics	**5.29E+04**	1.00E+01	2.83E+02	1.66E+00	2.98E+02	NA	NA	NA	NA	NA	1.99E+00	1.66E+00	8.21E-05	7.13E+01
Phenanthrene	**1.03E+03**	1.00E+01	2.83E+02	4.23E-05	2.98E+02	6.13E+02	1.31E+04	8.69E+02	4.06E-01	1.84E+04	1.99E+00	8.16E-06	8.21E-05	3.51E-04

TABLE 8 (continued)
SOIL TO INDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Conversion Factor µg/kg to g/g	SCS soil type in vadose zone	Vadose zone soil dry bulk density	Vadose zone soil water-filled porosity	Organic carbon partition coefficient	Vadose zone organic carbon fraction	Soil-water partition coefficient	Vadose zone soil total porosity	Vadose zone soil air-filled porosity	Conversion Factor g/cm^3 to $\mu g/m^3$	Source Vapor Conc.
	Conv01	ST_v	ρ_b	$\theta_{w,v}$	K_{oc}	$f_{oc,v}$	K_d	n_v	$\theta_{a,v}$	Conv03	C_{source}
Units:	µg/kg / g/g	unitless	g/cm^3	cm^3/cm^3	cm^3/g	unitless	cm^3/g	cm^3/cm^3	cm^3/cm^3	g/cm^3 / $\mu g/m^3$	$\mu g/m^3$
Formula:		(Note 11)	lookup	lookup	lookup	(0.002 for screening)	$K_{oc} * f_{oc}$	lookup	$n_v - \theta_{w,v}$		(Note 21)
Analyte											
C9-C12 Aliphatics	1.00E-09	SCL	1.63E+00	1.46E-01	1.50E+05	2.00E-03	3.00E+02	3.84E-01	2.38E-01	1.00E+12	1.10E+06
C9-C18 Aliphatics	1.00E-09	SCL	1.63E+00	1.46E-01	6.80E+05	2.00E-03	1.36E+03	3.84E-01	2.38E-01	1.00E+12	2.75E+06
Phenanthrene	1.00E-09	SCL	1.63E+00	1.46E-01	1.40E+04	2.00E-03	2.80E+01	3.84E-01	2.38E-01	1.00E+12	1.28E+01

TABLE 8 (continued)
SOIL TO INDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Depth below grade to bottom of enclosed space	Depth below grade to contamination	Source Building Separation	Diffusivity in air	Diffusivity in water	Vadose zone Effective Diffusion Coeff.	Total Overall Effective Diffusion Coeff.	Area of Enclosed Space Below Grade	Building Ventilation Rate	Pressure Diff. between soil & enclosed space	Vadose zone soil saturated hydraulic conductivity
	L_F	L_t	L_T	D_a	D_w	D_v^{eff}	D_T^{eff}	A_B	$Q_{building}$	ΔP	$K_{s,v}$
Units:	cm	cm	cm	cm^2/s	cm^2/s	cm^2/s	cm^2/s	cm^2	cm^3/s	$g/cm\text{-}s^2$	cm/hr
Formula:	(15 or 200 for screening)	(400 for screening)	$L_t - L_F$	lookup	lookup	(Note 13)	(Note 4)	(Note 2)	(Note 2a)	(40 for screening)	lookup
Analyte											
C9-C12 Aliphatics	2.00E+02	4.00E+02	2.00E+02	7.00E-02	1.00E-06	3.99E-03	3.99E-03	1.80E+06	2.54E+04	4.00E+01	5.50E-01
C9-C18 Aliphatics	2.00E+02	4.00E+02	2.00E+02	7.00E-02	5.00E-06	3.99E-03	3.99E-03	1.80E+06	2.54E+04	4.00E+01	5.50E-01
Phenanthrene	2.00E+02	4.00E+02	2.00E+02	3.33E-02	7.47E-06	2.13E-03	2.13E-03	1.80E+06	2.54E+04	4.00E+01	5.50E-01

TABLE 8 (continued)
SOIL TO INDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Conversion Factor hr to s	Viscosity of water at 10°C	Viscosity of water at system temp.	Density of water	Acceleration due to gravity	Vadose zone soil intrinsic permeability	Vadose zone residual soil water content	Vadose zone effective total fluid saturation	Vadose zone van Genuchten shape parameter	Vadose zone soil relative air permeability	Vadose zone soil effective vapor permeability
	Conv02	μ_{w-10}	μ_w	ρ_w	g	$k_{i,v}$	$\theta_{r,v}$	S_{te}	M_v	k_{rg}	k_v
Units:	s/hr	g/cm-s	g/cm-s	g/cm^3	cm/s^2	cm^2	cm^3/cm^3	unitless	unitless	unitless	cm^2
Formula:			(Note 16)	(0.999 for screening)		(Note 17)	lookup	(Note 18)	lookup	(Note 19)	(Note 20)
Analyte											
C9-C12 Aliphatics	3.60E+03	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09
C9-C18 Aliphatics	3.60E+03	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09
Phenanthrene	3.60E+03	1.31E-02	1.31E-02	9.99E-01	9.81E+02	2.04E-09	6.30E-02	2.59E-01	2.48E-01	8.59E-01	1.75E-09

TABLE 8 (continued)
SOIL TO INDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

	Floor-wall seam perimeter	Vapor viscosity at avg. soil temp.	Crack depth below grade	Total area of cracks	Crack-to-total area ratio	Equivalent crack radius	Avg. Vapor Flow Rate Into Bldg.	Foundation or Slab Thickness	Crack Effective Diffusion Coeff.	Infinite Source Indoor Attenuation Coeff.	Infinite Source Bldg. Conc.
	X_{crack}	μ_{TS}	Z_{crack}	A_{crack}	η	r_{crack}	Q_{soil}	L_{crack}	D^{crack}	α	$C_{building}$
Units:	cm	g/cm-s	cm	cm^2	unitless	cm	cm^3/s	cm	cm^2/s	unitless	$\mu g/m^3$
Formula:	(4000 for screening)	0.00018*(T'$_S$/298.15)^0.5	(= L_F for screening)	(400 for screening)	A_{crack}/A_B	$\eta(A_B/X_{crack})$	(Note 5)	(10 for screening)	(Note 1)	(Note 6)	$C_{source} * \alpha$
Analyte											
C9-C12 Aliphatics	4.00E+03	1.75E-04	2.00E+02	4.00E+02	2.22E-04	1.00E-01	1.21E+00	1.00E+01	3.99E-03	4.61E-05	5.07E+01
C9-C18 Aliphatics	4.00E+03	1.75E-04	2.00E+02	4.00E+02	2.22E-04	1.00E-01	1.21E+00	1.00E+01	3.99E-03	4.61E-05	1.27E+02
Phenanthrene	4.00E+03	1.75E-04	2.00E+02	4.00E+02	2.22E-04	1.00E-01	1.21E+00	1.00E+01	2.13E-03	4.48E-05	5.74E-04

TABLE 8 (continued)
SOIL TO INDOOR AIR - 95% UCL SOIL CONCENTRATIONS
FORMER BROOKFIELD MILL SITE

Notes:

Reference: *User's Guide for Evaluating Subsurface Vapor Intrusion into Buildings*, USEPA, June 19, 2003.

(1) Assumed equivalent to D_i^{eff} of soil layer i in contact with the floor

(2) For screening, A_B = 1,000,000 cm^2 for L_F <= 15 cm and A_B = 1,800,000 cm^2 for LF > 15 cm

(2a) For screening, $Q_{building}$ = 25,417 cm^3/s for L_F <= 15 cm and $Q_{building}$ = 16,944 cm^3/s for LF > 15 cm

(3) Purposely left blank

(4) $D_T^{eff} = L_T / (L_T / D_v^{eff})$

(5) $Q_{soil} = (2*\pi*\Delta P*k_v*X_{crack}) / (\mu_{TS}*\ln(2*Z_{crack}/r_{crack}))$

(6) $\alpha = [(D_T^{eff}*A_B/(Q_{building}*L_T))*EXP(Q_{soil}*L_{crack}/(D^{crack}*A_{crack}))]/[EXP(Q_{soil}*L_{crack}/(D^{crack}*A_{crack}))+(D_T^{eff}*A_B/(Q_{building}*L_T))+(D_T^{eff}*A_B/(Q_{soil}*L_T))*(EXP(Q_{soil}*L_{crack}/(D^{crack}*A_{crack}))-1)]$

(7) A function of the ratio T_B/T_C:

T_B/T_C	n
<0.57	0.30
0.57-0.71	$0.74(T_B/T_C)-0.116$
>0.71	0.41

If values are not available for calculation, result is NA.

(8) $\Delta H_{v,TS} = \Delta H_{v,B}*[(1-T_S/T_C)/(1-T_B/T_C)]^n$; if values are not available for calculation, result is NA.

(9) $H_{TS} = EXP[-\Delta H_{v,TS}/R_c*(1/T_S-1/T_R)]*H_R$; if values are not available for calculation, result assumed to be H_R

(10) Purposely left blank

(11) Refer to 12 SCS soil types - if no site-specific information is available, use SCL for screening.

(12) Purposely left blank

(13) $D_v^{eff} = D_a*(\theta_{a,v}^{3.33}/n_v^2)+(D_w/H'_{TS})(\theta_{w,v}^{3.33}/n_v^2)$

(14) Purposely left blank

(15) Purposely left blank

(16) $\mu_w = \mu_{w-10} * (T'_S / 283.15)^{0.5}$

(17) $k_{i,v} = K_{s,v} * 1/Conv02 * \mu_w / (\rho_w * g)$

(18) $S_{te} = (\theta_{w,v} - \theta_{r,v}) / (n_v - \theta_{r,v})$

(19) $k_{rg} = (1 - S_{te})^{0.5} * (1-S_{te}^{1/Mv})^{2Mv}$

(20) $k_v = k_{i,v} * k_{rg}$; note that the model is very sensitive to this parameter and if site-specific values are available, they should be used.

(21) $C_{source} = H'_{TS} * C_R * Conv01 * \rho_b / (\theta_{w,v} + K_d * \rho_b + H'_{TS} * \theta_{a,v}) * Conv02$

TABLE 9. SUMMARY OF MODELED AIR DATA
FORMER BROOKFIELD MILL SITE

	Air Concentrations (ug/m^3)	
	Outdoor Air EPC	**Indoor Air EPC[1]**
Analyte		
C9-C12 Aliphatics	2.6E-03	5.1E+01
C9-C18 Aliphatics	6.5E-03	1.3E+02
C11-C22 Aromatics	6.1E-04	NA
2-Methylnaphthalene	1.3E-06	NA
Phenanthrene	3.0E-08	5.7E-04

EPC - Exposure Point Concentration
NA - Not Applicable for this scenario, or not detected in specified media

TABLE 10
ORAL DOSE-RESPONSE VALUES FOR CHEMICALS OF POTENTIAL CONCERN
FORMER BROOKFIELD MILL SITE

CHEMICAL (a)	CHRONIC ORAL RfD (mg/kg/day)	CRITICAL EFFECTS	ORAL RfD CONFIDENCE	REF	SUBCHRONIC ORAL RfD (mg/kg/day)	REF	ORAL SLOPE FACTOR /(mg/kg/day)	WEIGHT OF EVIDENCE	REF
C9-C12 Aliphatics	0.1	hepatotoxicity	NA	MassDEP, 2006	1.0	MassDEP, 2006	NA	NA	MassDEP, 2006
C9-C18 Aliphatics	0.1	hepatotoxicity	NA	MassDEP, 2006	1.0	MassDEP, 2006	NA	NA	MassDEP, 2006
C19-C36 Aliphatics	2.0	hepatotoxicity	NA	MassDEP, 2006	6	MassDEP, 2006	NA	NA	MassDEP, 2006
C11-C22 Aromatics	0.03	nephrotoxicity	NA	MassDEP, 2006	0.30	MassDEP, 2006	NA	NA	MassDEP, 2006
2-Methylnaphthalene	0.004	lung	Low	MassDEP, 2006	0.04	MassDEP, 2006	NA	NA	MassDEP, 2006
Dibenz(a,h)anthracene	0.03	kidney effects	NA	MassDEP, 2006	0.3	MassDEP, 2006	7.3	B2	MassDEP, 2006
Aroclor-1260	0.00002	immune system	Med	MassDEP, 2006	0.00005	MassDEP, 2006	2	B2	MassDEP, 2006
Aluminum	1	developmental	NA	STSC '05	1	(b)	NA	NA	NA
Antimony	0.0004	general toxicity	Low	MassDEP, 2006	0.0004	MassDEP, 2006	NA	NA	MassDEP, 2006
Barium	0.07	increased blood pressure	Med.	MassDEP, 2006	0.07	MassDEP, 2006	NA	NA	MassDEP, 2006
Beryllium	0.002	gastrointestinal lesions	Low-med.	MassDEP, 2006	0.005	MassDEP, 2006	NA	NA	MassDEP, 2006
Chromium	0.003	NOEL	Low	MassDEP, 2006	0.02	MassDEP, 2006	NA	NA	MassDEP, 2006
Cobalt	0.02	blood	NA	STSC '05	0.02	(b)	NA	NA	NA
Copper	0.03	kidney	NA	STSC '05	0.3	STSC '05	NA	D	IRIS '07
Iron	0.3	liver/GI system	Med.	STSC '05	0.3	(b)	NA	NA	NA
Lead	0.00075	CNS effects	NA	MassDEP, 2006	0.00075	MassDEP, 2006	NA	B2	MassDEP, 2006
Manganese	0.07	CNS effects	Med.	IRIS '07	0.07	(b)	NA	D	IRIS '07
Mercury	0.0003	autoimmune effects	High	MassDEP, 2006	0.0003	MassDEP, 2006	NA	D	MassDEP, 2006
Nickel	0.02	decrease body weight	Med.	MassDEP, 2006	0.02	MassDEP, 2006	NA	A	MassDEP, 2006
Selenium	0.005	liver	High	MassDEP, 2006	0.005	MassDEP, 2006	NA	D	MassDEP, 2006
Silver	0.005	skin	Low	MassDEP, 2006	0.005	MassDEP, 2006	NA	D	MassDEP, 2006
Thallium	0.00008	blood	Low	MassDEP, 2006	0.0008	MassDEP, 2006	NA	NA	MassDEP, 2006
Vanadium	0.009	kidney toxicity	Low	MassDEP, 2006	0.009	MassDEP, 2006	NA	D	IRIS '07
Zinc	0.3	Decreased enzyme activity	Med.	MassDEP, 2006	0.3	MassDEP, 2006	NA	D	MassDEP, 2006

NOTES:
(a) This table includes analytes detected in all media.
(b) Chronic RfD selected as subchronic RfD
(c) Slope factor calculated based on potency relative to benzo(a)pyrene.

ABBREVIATIONS:
RfD - Reference dose or MassDEP substitute for reference dose
NA - Not applicable, not available, no data, or not determined
REF - References

REFERENCES (in order of priority):
IRIS. USEPA, 2007. Integrated Risk Information System.
MassDEP, 2006. MCP Numeric Standards Derivation (http://www.mass.gov/dep/cleanup/laws/pubnot04.htm)
STSC. Superfund Technical Support Center.

TABLE 11
INHALATION DOSE-RESPONSE VALUES FOR CHEMICALS OF POTENTIAL CONCERN
FORMER BROOKFIELD MILL SITE

CHEMICAL (a)	CHRONIC INHALATION RfC (mg/m³)	CRITICAL EFFECTS	INHALATION RfC CONFIDENCE	REF	INHALATION UNIT RISK 1/(mg/m³)	WEIGHT OF EVIDENCE	REF	SUBCHRONIC INHALATION RfC (mg/m³)	REF
C9-C12 Aliphatics	0.2	neurotoxicity	NA	MassDEP, 2006	NA	NA	MassDEP, 2006	0.2	MassDEP, 2006
C9-C18 Aliphatics	0.2	neurotoxicity	NA	MassDEP, 2006	NA	NA	MassDEP, 2006	0.2	MassDEP, 2006
C19-C36 Aliphatics	NA	NA	NA	MassDEP, 2006	NA	NA	MassDEP, 2006	NA	MassDEP, 2006
C11-C22 Aromatics	0.05	hepatotoxicity	NA	MassDEP, 2006	NA	NA	MassDEP, 2006	0.05	MassDEP, 2006
2-Methylnaphthalene	0.05	liver	NA	MassDEP, 2006	NA	D	IRIS '07	0.5	MassDEP, 2006
Dibenz(a,h)anthracene	0.05	liver	NA	MassDEP, 2006	2.09E+00	B2	MassDEP, 2006	0.5	MassDEP, 2006
Phenanthrene	0.05	liver	NA	MassDEP, 2006	NA	D	MassDEP, 2006	0.5	MassDEP, 2006
Aroclor-1260	0.00002	immune system	NA	MassDEP, 2006	1.00E-01	B2	MassDEP, 2006	0.00002	MassDEP, 2006
Aluminum	NA	NA	NA	NA	NA	NA	NA	NA	NA
Antimony	0.01	NA	NA	MassDEP, 2006	NA	NA	MassDEP, 2006	0.01	MassDEP, 2006
Barium	0.0005	developmental	Low	MassDEP, 2006	NA	NA	MassDEP, 2006	0.005	MassDEP, 2006
Beryllium	0.00002	respiratory	Med.	MassDEP, 2006	2.40E+00	NA	MassDEP, 2006	0.00002	MassDEP, 2006
Chromium	0.0001	enzyme leakage	Med.	MassDEP, 2006	1.20E+01	NA	MassDEP, 2006	0.0003	MassDEP, 2006
Cobalt	NA	NA	NA	NA	NA	NA	NA	NA	NA
Copper	NA	NA	NA	IRIS '07	NA	D	IRIS '07	NA	NA
Iron	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead	0.001	CNS effects	NA	MassDEP, 2006	NA	B2	MassDEP, 2006	0.001	MassDEP, 2006
Manganese	0.00005	neurological effects	Med.	IRIS '07	NA	D	IRIS '07	0.00005	(b)
Mercury	0.0003	NA	NA	MassDEP, 2006	NA	D	MassDEP, 2006	0.0003	MassDEP, 2006
Nickel	0.001	NA	NA	MassDEP, 2006	4.80E-01	A	MassDEP, 2006	0.001	MassDEP, 2006
Selenium	0.003	NA	NA	MassDEP, 2006	NA	D	MassDEP, 2006	0.003	MassDEP, 2006
Silver	0.00014	NA	NA	MassDEP, 2006	NA	D	MassDEP, 2006	0.00014	MassDEP, 2006
Thallium	0.000014	NA	NA	MassDEP, 2006	NA	NA	MassDEP, 2006	0.000014	MassDEP, 2006
Vanadium	0.001	NA	NA	MassDEP, 2006	NA	NA	MassDEP, 2006	0.001	MassDEP, 2006
Zinc	0.0014	NA	NA	MassDEP, 2006	NA	D	MassDEP, 2006	0.0014	MassDEP, 2006

NOTES:

a. This table includes analytes detected in soil and groundwater.

b. Chronic RfC adopted as subchronic RfC

REFERENCES (in order of priority):

IRIS. USEPA, 2007. Integrated Risk Information System.

MassDEP, 2006. MCP Numerical Standards Derivations (January 2006)

ABBREVIATIONS:

RfC - Reference Concentration or MassDEP substitute for reference concentration

NA - Not available, not applicable, no data, or not determined

REF - References

Weight of Evidence:

A - Human carcinogen

B1 - Probable human carcinogen - indicates that limited human data are available

B2 - Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans

C - Possible human carcinogen

D - Not classifiable as a human carcinogen (by the oral route)

E - Evidence of noncarcinogenicity