100 Foxborough Blvd., Suite 250
Foxborough, MA 02035
tel: 508-698-3034 fax: 508-698-0843
www.westonandsampson.com

April 26, 2016

Ms. Christine Stickney
Director, Planning and Community Development
Town of Braintree
90 Pond Street, Second Floor
Braintree, MA 02184

Re: Focused Method 3 Risk Characterization
Former BELD Facility
44 Allen Street
Braintree, Massachusetts

Dear Ms. Stickney:

Weston & Sampson is pleased to provide this letter report summarizing the results of our Focused Method 3 Risk Characterization performed for 44 Allen Street, Braintree, Massachusetts (the "Site"). The Site consists of a 1.6 acre parcel of land which was previously occupied by the Braintree Electric Light Department (BELD). BELD operated a power station at the Site from the 1890's until the 1970's when the Site was then used as storage / office space. The Site buildings are now vacant and the Site is owned by the Town of Braintree.

As you are aware, Weston & Sampson performed a Phase II Environmental Site Assessment (ESA) of the Site in January and February 2016. The Phase II ESA identified petroleum impacted soil at concentrations above Massachusetts Department of Environmental Protection (DEP) Reportable Concentration (RC) S-1 standards in the Area of a Former Gasoline UST – South of BELD Office Building and the Area of a Former Fuel Oil Tank South of the Former Boiler House. Additionally concentrations of PAHs and lead were identified above RCS-1 in fill material soil samples collected at the Site. Groundwater impacts were not identified above applicable standards. In accordance with the Massachusetts Contingency Plan (MCP), 310 40.0000, the reportable condition requires the Town notify the DEP by June 24, 2016, or within 120 days of the Town's knowledge of the reportable condition.

A multi-family residential development is planned for the Site. This risk characterization was performed to evaluate risk for future Site use including residential, employee, and construction worker exposures to Site soil. The risk characterization was performed using data obtained during our Phase II ESA and will assist in developing a remediation and MCP regulatory closure strategy. A detailed summary of the risk characterization is provided below. See attached Figures, Tables and Attachments for supporting information.

Summary of Soil Data

Soil samples collected during the Phase II ESA were analyzed for total petroleum hydrocarbons (TPH), extractable petroleum hydrocarbons (EPH), polycyclic aromatic hydrocarbons (PAHs), volatile petroleum hydrocarbons (VPH), volatile organic compounds (VOCs), 8 RCRA Metals and polychlorinated biphenyls (PCBs). A statistical summary of all soil data (regardless of depth) is provided as Table 1. Table 2 presents a statistical summary of surficial soil data collected from 0 to 3 feet below grade at the Site. All soil analytical data is presented in Attachment A.

Lead was found to be the constituent that drove the calculated potential health risks during this evaluation. Detections of VOCs, VPH and EPH fractions, PAHs, TPH, and other metals besides lead were of less concern. PCBs were not detected above detection limits in any of the soil samples analyzed.

VPH fractions were detected with the highest concentrations in soil collected from test pit TP-1 (6 to 9 feet), located in the Area of a Former Gasoline UST – South of BELD Office Building. Detections of VPH fractions in this sample were greater than DEP Method 1 S-1 GW-2/GW-3 soil standards. Similarly, TP-1 (6 to 9 feet) was the only soil sample that contained detectable concentrations of VOCs. Detected concentrations of VOCs were well below Method 1 S-1 soil standards.

The highest concentrations of EPH fractions were detected in soil sample TP-4 (2 to 5 feet) located in the Area of a Former Fuel Oil Tank South of the Former Boiler House. Detected concentrations of EPH fractions were greater than Method 1 S-1 soil standards. As shown in Table 2, detected concentrations of EPH fractions were higher in surface soil (0 to 3 feet) than all soil across the Site.

Detections of TPH ranged from 120 to 910 mg/kg; with the highest detections at TP-9 (0 to 3 feet), located between the former boiler house building and the switch house building. As with the maximum concentrations of TPH, the highest concentrations of PAHs were detected in TP-9 (0 to 3 feet).

Concentrations of lead in soil samples ranged from 26 to 1,700 mg/kg with an average concentration of lead of 383 mg/kg across the Site and 680 mg/kg in surface soil from 0 to 3 feet below grade. The highest detected concentration of lead was detected in test pit TP-9 (0 to 3 feet). The highest concentrations of all metals were detected in TP-9 and TP-8. As shown in Table 2, detected concentrations of lead were higher in surficial soil (0 to 3 feet) compared to all soil across the Site.

An evaluation of constituents of concern in soil indicates that while residual concentrations of certain samples are elevated compared to other parts of the Site, these detections do not meet the criteria of being a hotspot as they are not located in a central location, nor are they more than ten times the concentrations detected in other portions of the Site. Detections of contaminants in soil are heterogeneously distributed throughout the Site as would be expected at a Site with fill and from former use as an electric power station dating back to the 1890's. Based on this evaluation, residual concentrations of constituents at the Site are not considered to be hotspots. This is an important conclusion as the MCP allows site-wide averaging to develop exposure point concentrations, provided there are no hot spots.

Summary of Groundwater Data

Groundwater samples collected during the Phase II ESA were analyzed for EPH, PAHs, VPH and VOCs. A statistical summary of groundwater analytical data is presented on Table 3. As shown on Table 3, naphthalene was detected in the groundwater sample collected from monitoring well WSE-101 and VPH, ethylbenzene, and xylenes were detected in the groundwater sample collected from WSE-102. Detected concentrations were well below DEP Method 1 GW-2/GW-3 groundwater standards. No constituents were identified above detection limits in WSE-103.

Exposure Point Concentrations

The Exposure Point Concentrations (EPCs) for soil from this Site were calculated in two different ways:

- the average of all soil samples across the Site (Table 1) regardless of depth; and
- the average of surficial soil samples collected at from 0 to 3 feet below grade (Table 2).

For samples that contained non-detectable concentrations of individual constituents, one-half of the laboratory detection limit was used as the concentration for the purpose of calculating averages.

Several PAHs including dibenzofuran, di-n-butylphthalate, and m/p-methylphenol were not evaluated in this risk characterization because there are no promulgated toxicity values for these constituents. Based on the generally low frequency of detection (they were each detected once in soil) and the low detected concentrations of these constituents, the potential risks associate with exposure to these PAHs is expected to be de-minimus (i.e., at least an order of magnitude below DEP risk limits). For this reason, these PAHs were not included in the risk calculations.

Detected PAHs and metals were compared to DEP published Background Concentrations in Natural Soil. The maximum concentrations of two metals, arsenic and chromium, were less than background concentrations and were therefore, eliminated from consideration in this risk evaluation (refer to Table 4).

Calculated Human Health Risks

Under Method 3 risk characterization, cancer and non-cancer risks are calculated separately for each receptor. The non-cancer risk is characterized by a hazard quotient (HQ_I) which is the ratio of the receptor's exposure (ADD) to the maximum allowable exposure level (RfD) for each contaminant and exposure pathway or:

A condition of No Significant Risk (NSR) for non-cancer effects exists if the total Site Hazard Index (HI) is equal to or less than 1 for each receptor as follows:

$$HQ_1 = ADDi / RfDi$$

$$HI = \Sigma \frac{ADD}{RfD} = \Sigma \frac{EPC \times EF \times ED \times EP \times PSF}{BW \times AP \times RfD}$$

where:

ADD	=	Average Daily Dose, mg/kg-day
RfD	=	Reference Dose, mg/kg-day
EPC	=	Exposure-Point Concentration of contaminant, mg/kg
EF	=	Exposure Frequency (events/day)
ED	=	Exposure Duration (time/event)
EP	=	Exposure Period (time)
PSF	=	Pathway/receptor-specific factor for ingestion and dermal contact
BW	=	Body Weight (kg)

AP = Averaging Period (time)

The LADD is calculated in the same manner as the ADD, except that the averaging period is over a lifetime of 70 years. A condition of NSR for cancer effects exists if the Excess Lifetime Cancer Risk (ELCR) is less than or equal to 1 x 10^{-5}, shown in the following equation:

$$ELCR = \Sigma\ LADD * CSF = \Sigma\ \frac{EPC \times EF \times ED \times EP \times PSF \times CSF}{BW \times AP}$$

Risk Calculation Results

The total Site cancer and non-cancer risk calculations, using all soil from the Site, are provided in residential, commercial employee, and construction worker ShortForm (or ShortForm-modified for the employee) spreadsheets in Attachment B through D and Table 5 and are summarized below:

All Soil - Risk Calculation Results

Receptor	Hazard Index		ELCR
	Subchronic	Chronic	
Resident	**2**	1	9 X 10^{-6}
Employee	NA	0.1	8 X 10^{-6}
Construction Worker	0.4	NA	2 X 10^{-7}
DEP Acceptable Risk	1	1	1 X 10^{-5}

NA=Not Applicable.
Bold Red=Above DEP Acceptable Risk

As shown above, utilizing all soil the subchronic non-cancer risk for the future resident receptor ***is above DEP's acceptable limit***. The chronic non-cancer risks for the future resident are equivalent to, but ***do not exceed DEP's acceptable non-cancer limit***. The cancer risks for the future resident are less than DEP's acceptable cancer limit. The non-cancer and cancer risks for the employee and construction worker receptors are ***below DEP's acceptable limits***.

The total Site cancer and non-cancer risk calculations, using surficial soil (0 to 3 feet) from the Site, are provided in residential and employee ShortForm (or ShortForm-modified for the employee) spreadsheets in Attachment B through D and are summarized below:

Surficial Soil 0-3'- Risk Calculation Results

Receptor	Hazard Index		ELCR
	Subchronic	Chronic	
Resident	**3**	**2**	1 X 10^{-5}
Employee	NA	0.2	2 X 10^{-6}
DEP Acceptable Risk	1	1	1 X 10^{-5}

As shown above utilizing surficial soil 0 to 3 feet, the subchronic and chronic non-cancer risk for the future resident receptor is ***above DEP's acceptable limit***. The cancer risks for the future

resident are ***equal to DEP's acceptable cancer limit***. The non-cancer and cancer risks for the employee receptor are ***below DEP's acceptable limits***.

Summary of Findings

In summary, utilizing the existing soil data set, the findings of this risk characterization indicate that a condition of No Significant Risk of harm to human health ***does not exist for potential future residents*** at the Site from exposure to Site soils. However, it is noted that the findings are primarily due to the detection of lead in surficial soil (0 to 3 feet) in the area of test pit TP-9 where a concentration of 1,700 mg/kg was identified. Lead throughout the remainder of the Site ranges from 26 to 410 mg/kg with an average of 163 mg/kg. This average would ***not pose a risk for residents*** using a Method 3 risk characterization. As such, there is potential that additional assessment and/or soil removal in the area of TP-9 could be performed to reduce site wide exposure point concentrations to acceptable levels for residential development. In lieu of additional assessment and soil removal, plans for residential development should include capping existing soil in planned landscaped areas with 3 feet of clean fill material and with asphalt in planned drive and parking areas.

Potential risks calculated for employees and construction workers were less than DEP acceptable limits. Therefore, a condition of ***no significant risk of harm to human health does exist*** for potential employee and construction worker receptors.

Please note, based on our discussions with you, we assume that petroleum impacted soil identified in the Area of a Former Gasoline UST – South of BELD Office Building and the Area of a Former Fuel Oil Tank South of the Former Boiler House will be excavated and removed as part of Site remediation. As such, an evaluation of potential impacts to indoor air from petroleum impacted soil in these locations was not performed as part of this risk characterization.

If you have any questions regarding this letter report, please do not hesitate to contact the undersigned at (978) 532-1900.

Very truly yours,
WESTON & SAMPSON INC.

Sean F. Healey, LSP
Team Leader

Marie Rudiman
Sr. Risk Assessor

George Naslas, P.G., LSP
Vice President

Attachments: Figures, Tables 1 - 4, Attachments A through D

FIGURES

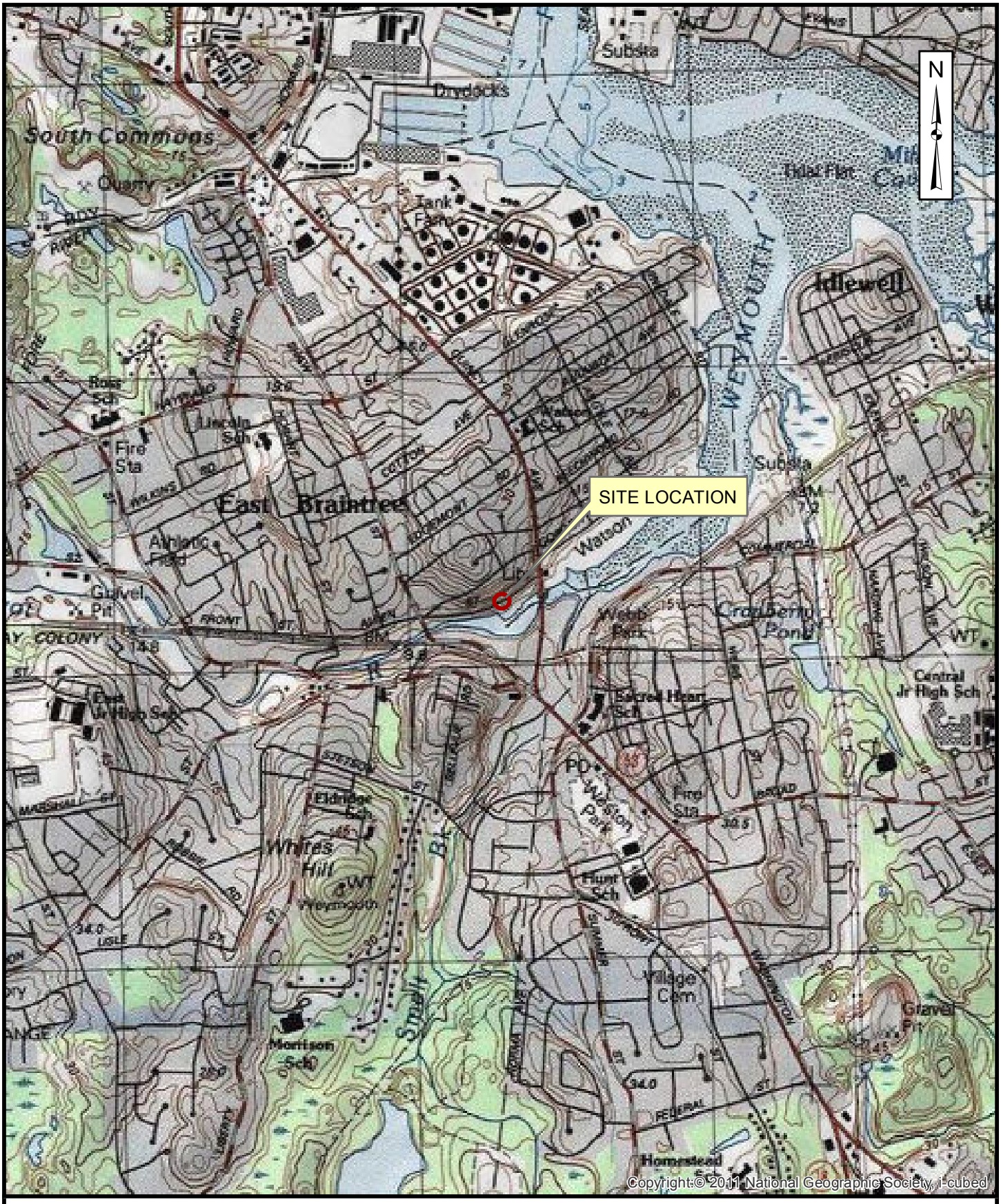


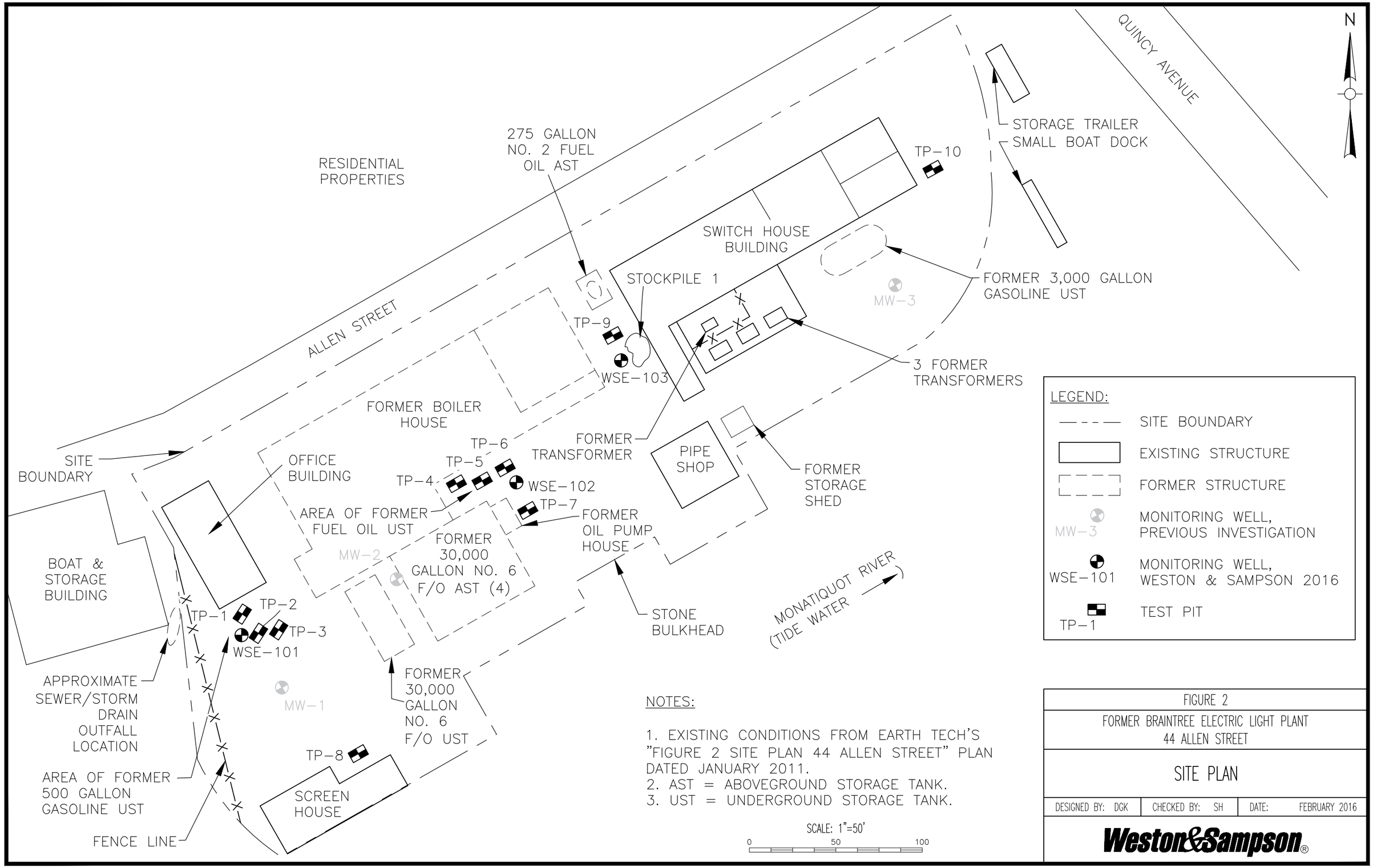
FIGURE 1
TOWN OF BRAINTREE, MASSACHUSETTS
44 Allen Street

LOCUS MAP

0 2,000 4,000 Feet

Weston&Sampson

Q:\Resources\Templates\ThemeMaps\MA - Locus Map.mxd 11/30/2007 10:01:39 AM kastanom



LEGEND:

- SITE BOUNDARY
- EXISTING STRUCTURE
- FORMER STRUCTURE
- MW-3 — MONITORING WELL, PREVIOUS INVESTIGATION
- WSE-101 — MONITORING WELL, WESTON & SAMPSON 2016
- TP-1 — TEST PIT

NOTES:

1. EXISTING CONDITIONS FROM EARTH TECH'S "FIGURE 2 SITE PLAN 44 ALLEN STREET" PLAN DATED JANUARY 2011.
2. AST = ABOVEGROUND STORAGE TANK.
3. UST = UNDERGROUND STORAGE TANK.

SCALE: 1"=50'

0 50 100

FIGURE 2

FORMER BRAINTREE ELECTRIC LIGHT PLANT
44 ALLEN STREET

SITE PLAN

DESIGNED BY: DGK	CHECKED BY: SH	DATE: FEBRUARY 2016

Weston&Sampson®

Z:\MA-Foxboro-Projects\Braintree, MA\Braintree Electric- Allen Street\CADD\Figure2 02.11.2016.dwg

TABLES

Table 1
Summary of Analytical Data for All Soil Samples
Former BELD Property
44 Allen Street
Braintree, Massachusetts

Constituent	Frequency of Detection	Range Detected (mg/kg)			Location of Maximum Detected Concentration	Arithmetic Mean Concentration (mg/kg)
VPH (MADEP-VPH-04-1.1)						
C5-C8 Aliphatics	1 / 4		790		TP-1	206
C9-C10 Aromatics	2 / 4	91	-	440	TP-1	135
C9-C12 Aliphatics	2 / 4	96	-	500	TP-1	152
Target VOCs						
Benzene	1 / 9		1		TP-1	0.18
Ethylbenzene	1 / 9		12		TP-1	1
Naphthalene	1 / 9		10		TP-1	1
EPH (MADEP-EPH-04-1.1)						
C9-C18 Aliphatics	1 / 2		1,500		TP-4	753
C19-C36 Aliphatics	2 / 2	24	-	3,100	TP-4	1,562
C11-C22 Aromatics	2 / 2	37	-	5,600	TP-4	2,819
Target PAHs						
Acenaphthene	3 / 7	0.2	-	6	TP-9	1
Acenaphthylene	2 / 7	0.2	-	1.1	TP-9	0.3
Anthracene	6 / 7	0.2	-	12	TP-9	2
Benzo(a)anthracene	6 / 7	0.9	-	24	TP-9	5
Benzo(a)pyrene	6 / 7	0.8	-	21	TP-9	4
Benzo(b)fluoranthene	6 / 7	1	-	28	TP-9	6
Benzo(g,h,i)perylene	6 / 7	0.5	-	8	TP-9	2
Benzo(k)fluoranthene	6 / 7	0.4	-	9	TP-9	2
Chrysene	6 / 7	1	-	23	TP-9	5
Dibenz(a,h)anthracene	4 / 7	0.2	-	4	TP-9	1
Dibenzofuran	1 / 5		6		TP-9	1
Di-n-butylphthalate	1 / 5		0.4		TP-9	0.3
Fluoranthene	6 / 7	2	-	63	TP-9	12
Fluorene	2 / 7	2	-	6	TP-9	1
Indeno(1,2,3-cd)pyrene	6 / 7	0.6	-	8	TP-9	2
2-Methylnaphthalene	1 / 7		3		TP-9	1
m/p-Methylphenol	1 / 5		0.4		TP-9	0.3
Naphthalene	1 / 7		5		TP-9	1
Phenanthrene	6 / 7	0.8	-	70	TP-9	12
Pyrene	7 / 7	2	-	56	TP-9	12
Metals						
Arsenic	3 / 5	8	-	10	TP-8	6
Barium	5 / 5	17	-	250	TP-9	111
Cadmium	5 / 5	0.37	-	3	TP-9	1
Chromium	5 / 5	7	-	27	TP-8	14
Lead	7 / 7	26	-	1,700	TP-9	383
Mercury	5 / 5	0.04	-	3.50	TP-9	0.86
Total Petroleum Hydrocarbons	5 / 5	120	-	910	TP-9	484

Notes:

1. For the purpose of calculating arithmetic mean concentrations, one-half the method detection limit was used to represent the concentrations of constituents reported as non-detects (ND).

2. Analytical results were based on samples collected in January and February 2016.

Table 2
Summary of Analytical Data for Surface Soil Samples
Former BELD Property
44 Allen Street
Braintree, Massachusetts

Constituent	Frequency of Detection	Range Detected (mg/kg)			Location of Maximum Detected Concentration	Arithmetic Mean Concentration (mg/kg)
VPH (MADEP-VPH-04-1.1)						
C9-C10 Aromatics	1 / 1	91	-	91	TP-4	91
C9-C12 Aliphatics	1 / 1	96	-	96	TP-4	96
EPH (MADEP-EPH-04-1.1)						
C9-C18 Aliphatics	1 / 1		1,500		TP-4	1,500
C19-C36 Aliphatics	1 / 1		3,100		TP-4	3,100
C11-C22 Aromatics	1 / 1		5,600		TP-4	5,600
Target PAHs						
Acenaphthene	2 / 4	0.9	-	6	TP-9	2
Acenaphthylene	2 / 4	0.2	-	1.1	TP-9	0.4
Anthracene	3 / 4	0.5	-	12	TP-9	3
Benzo(a)anthracene	3 / 4	1.2	-	24	TP-9	7
Benzo(a)pyrene	3 / 4	1.1	-	21	TP-9	6
Benzo(b)fluoranthene	3 / 4	1	-	28	TP-9	8
Benzo(g,h,i)perylene	3 / 4	0.8	-	8	TP-9	3
Benzo(k)fluoranthene	3 / 4	0.6	-	9	TP-9	3
Chrysene	3 / 4	1	-	23	TP-9	7
Dibenz(a,h)anthracene	2 / 4	0.3	-	4	TP-9	1
Dibenzofuran	1 / 3		6		TP-9	2
Di-n-butylphthalate	1 / 3		0.4		TP-9	0.3
Fluoranthene	3 / 4	3	-	63	TP-9	18
Fluorene	2 / 4	2	-	6	TP-9	2
Indeno(1,2,3-cd)pyrene	3 / 4	0.8	-	8	TP-9	3
2-Methylnaphthalene	1 / 4		3		TP-9	1
m/p-Methylphenol	1 / 3		0.4		TP-9	0.3
Naphthalene	1 / 4		5		TP-9	1
Phenanthrene	3 / 4	2.2	-	70	TP-9	19
Pyrene	4 / 4	3	-	56	TP-9	19
Metals						
Arsenic	2 / 3	8	-	10	TP-8	6
Barium	3 / 3	17	-	250	TP-9	139
Cadmium	3 / 3	0.46	-	3	TP-9	1
Chromium	3 / 3	8	-	27	TP-8	16
Lead	3 / 3	29	-	1,700	TP-9	680
Mercury	3 / 3	0.05	-	3.50	TP-9	1.32
Total Petroleum Hydrocarbons	3 / 3	120	-	910	TP-9	437

Notes:

1. For the purpose of calculating arithmetic mean concentrations, one-half the method detection limit was used to represent the concentrations of constituents reported as non-detects (ND).

2. Analytical results were based on samples collected in January and February 2016.

Table 3
Groundwater Analytical Results
Former BELD Property
44 Allen Street
Braintree, Massachusetts

Parameters	Units	MCP - Method 1		WSE-101	WSE-102	WSE-103
		GW-2	GW-3			
Sample Date				**2/10/2016**	**2/10/2016**	**2/10/2016**
VPH						
C5-C8 Aliphatics	µg/L	3,000	50,000	<100	**280**	<100
C9-C10 Aromatics	µg/L	4,000	50,000	<100	**160**	<100
C9-C12 Aliphatics	µg/L	5,000	50,000	<100	<100	<100
Target VOCs						
Benzene	µg/L	1,000	10,000	<1.0	<1.0	<1.0
Ethylbenzene	µg/L	20,000	5,000	<1.0	**20**	<1.0
Methyl tert-butyl ether	µg/L	50,000	50,000	<1.0	<1.0	<1.0
Naphthalene	µg/L	700	20,000	<5.0	<5.0	<5.0
Toluene	µg/L	50,000	40,000	<1.0	<1.0	<1.0
m-Xylene & p-Xylene	µg/L	NS	NS	<2.0	**8.0**	<2.0
o-Xylene	µg/L	NS	NS	<1.0	<1.0	<1.0
Total Xylenes	ug/L	3,000	5,000	<2.0	**8.0**	<2.0
EPH						
C9-C18 Aliphatics	µg/L	5,000	50,000	<100	<100	<100
C19-C36 Aliphatics	µg/L	NS	50,000	<100	<100	<100
C11-C22 Aromatics	µg/L	50,000	5,000	<100	<100	<100
Target PAHs						
Acenaphthene	µg/L	NS	10,000	<2.0	<2.0	<2.0
Acenaphthylene	µg/L	10,000	40	<2.0	<2.0	<2.0
Anthracene	µg/L	NS	30	<2.0	<2.0	<2.0
Benzo[a]anthracene	µg/L	NS	1,000	<2.0	<2.0	<2.0
Benzo[a]pyrene	µg/L	NS	500	<2.0	<2.0	<2.0
Benzo[b]fluoranthene	µg/L	NS	400	<2.0	<2.0	<2.0
Benzo[g,h,i]perylene	µg/L	NS	20	<2.0	<2.0	<2.0
Benzo[k]fluoranthene	µg/L	NS	100	<2.0	<2.0	<2.0
Chrysene	µg/L	NS	70	<2.0	<2.0	<2.0
Dibenz(a,h)anthracene	µg/L	NS	40	<2.0	<2.0	<2.0
Fluoranthene	µg/L	NS	200	<2.0	<2.0	<2.0
Fluorene	µg/L	NS	40	<2.0	<2.0	<2.0
Indeno[1,2,3-cd]pyrene	µg/L	NS	100	<2.0	<2.0	<2.0
2-Methylnaphthalene	µg/L	2,000	20,000	<2.0	<2.0	<2.0
Naphthalene	µg/L	700	20,000	**5.2**	<2.0	<2.0
Phenanthrene	µg/L	NS	10,000	<2.0	<2.0	<2.0
Pyrene	µg/L	NS	20	<2.0	<2.0	<2.0

Abbreviations:
EPH = Extractable Petroleum Hydrocarbons
VPH = Volatile Petroleum Hydrocarbons
PAHs = Polycyclic Aromatic Hydrocarbons
VOCs = Volatile Organic Compounds
µg/L= micrograms per Liter
< = parameters not detected above laboratory
NS= No Standard
-- = Not Analyzed

Notes:
BOLD = Exceeds laboratory detection limit.

Analytical results compared to the Massachusetts Contingency
Plan (MCP) Reportable Concentration and Method 1 Cleanup
Standards 310 CMR 40.0000, revised April 2014

Table 4
Comparison of Detected PAHs and Metals in Soil to Massachusetts Background Concentrations
Former BELD Property
44 Allen Street
Braintree, Massachusetts

Constituent	Maximum Detected Concentration mg/kg	Massachusetts Background Concentration In Natural Soil mg/kg	
Target PAHs			
Acenaphthene	6	0.5	*
Acenaphthylene	1	0.5	*
Anthracene	12	1	*
Benzo(a)anthracene	24	2	*
Benzo(a)pyrene	21	2	*
Benzo(b)fluoranthene	28	2	*
Benzo(g,h,i)perylene	8	1	*
Benzo(k)fluoranthene	9	1	*
Chrysene	23	2	*
Dibenz(a,h)anthracene	4	0.5	*
Dibenzofuran	6	NA	
Di-n-butylphthalate	0.4	NA	
Fluoranthene	63	4	*
Fluorene	6	1	*
Indeno(1,2,3-cd)pyrene	8	1	*
2-Methylnaphthalene	3	0.5	*
m/p-Methylphenol	0.4	NA	
Naphthalene	5	0.5	*
Phenanthrene	70	3	*
Pyrene	56	4	*
Metals			
Arsenic	10	20	
Barium	250	50	*
Cadmium	3	2	*
Chromium	27	30	
Lead	1,700	100	*
Mercury	4	0.3	*

Notes:

1. The Massachusetts Background Concentration was obtained from MADEP (2002) Characterizing Risks Posed by Petroleum Contaminated Sites: Implementation of the MADEP VPH/EPH Approach, Final Policy, Policy #WSC-02-411

2. * Indicates maximum detected concentration in Site soil exceeds background concentration in natural soil.

Table 5
Summary of Results
Former BELD Property
44 Allen Street
Braintree, Massachusetts

Potential Receptor	Exposure Media	Exposure and Migration Pathway	Hazard Index Subchronic	Hazard Index Chronic	ELCR
Arithmetic Mean Concentrations All Soil					
On-Site Resident	Surface and Subsurface Soil	Incidental Ingestion and Dermal Contact	2	1	9E-06
		Total:	**2**	**1**	**9E-06**
		DEP Risk Limit:	1	1	1E-05
		Exceeds DEP Risk Limit?	**YES**	**NO***	**NO**
On-Site Employee	Surface and Subsurface Soil	Incidental Ingestion and Dermal Contact	NC	0.1	8E-06
		Total:	**NC**	**0.1**	**8E-06**
		DEP Risk Limit:	1	1	1E-05
		Exceeds DEP Risk Limit?	**NO**	**NO**	**NO**
Construction Worker	Surface and Subsurface Soil	Incidental Ingestion and Dermal Contact and Inhalation of Soil-Derived Particulates in Air	0.4	NA	2E-07
		Total:	**0.4**	**NC**	**2E-07**
		DEP Risk Limit:	1.0	1.0	1E-05
		Exceeds DEP Risk Limit?	**NO**	**NO**	**NO**
Arithmetic Mean Concentrations Surface Soil (0 to 3 feet)					
On-Site Resident	Surface Soil	Incidental Ingestion and Dermal Contact	3	2	1E-05
		Total:	**3**	**2**	**1E-05**
		DEP Risk Limit:	1.0	1.0	1E-05
		Exceeds DEP Risk Limit?	**YES**	**YES**	**NO***
On-Site Employee	Surface Soil	Incidental Ingestion and Dermal Contact	NC	0.2	2E-06
		Total:	**NC**	**0.2**	**2E-06**
		DEP Risk Limit:	1.0	1.0	1E-05
		Exceeds DEP Risk Limit?	**NO**	**NO**	**NO***

1. NA = Not Applicable, NC = Not Calculated, ELCR = Excess Lifetime Cancer Risk.

2. * Estimated risks are equivalent but do not exceed MADEP risk limits. Due to the conservative nature of assumptions used in this Method 3 Risk Characterization, it is likely that true risks are less than those calculated. Rounding to the single digit is applicable for Method 3 Risk Characterizations. MADEP, 2008, Technical Update: Expressing the Precision of Exposure Point Concentrations and Risk Estimates in MCP Risk Characterizations.

ATTACHMENT A

All Soil Data
Former BELD Property
44 Allen Street
Braintree, Massachusetts

Sample ID:	TP-1		TP-3		TP-4		TP-5		TP-7		TP-8		TP-9		TP-10		Stockpile 1	
Sample Date:	1/29/16		1/29/16		2/2/16		2/2/16		2/2/16		1/29/16		1/29/16		1/29/16		1/29/16	
Depth:	6-9'		6-9'		2-5'		4-7'		3-6'		0-3'		0-3'		0-3'		NA	
ANALYTES	*Result*	*MDL*	*Result*	*MDL*	*Result*	*MDL*	*Result*	*MDL*	*Result*	*MDL*	*Result*	*MDL*	*Result*	*MDL*	*Result*	*MDL*	*Result*	*MDL*
VPH (MADEP-VPH-04-1.1)																		
C5-C8 Aliphatics	790		ND	12	ND	49	ND	8.4										
C9-C10 Aromatics	440		ND	12	91		ND	8.4										
C9-C12 Aliphatics	500		ND	12	96		ND	8.4										
Target VOCs																		
Benzene	1.4		ND	0.062	ND	0.24	ND	0.042	ND	0.0022	ND	0.0014	ND	0.0014	ND	0.0014	ND	0.0023
Ethylbenzene	12		ND	0.062	ND	0.24	ND	0.042	ND	0.0022	ND	0.0014	ND	0.0014	ND	0.0014	ND	0.0023
Methyl-tert-butyl ether	ND	1.4	ND	0.062	ND	0.24	ND	0.042	ND	0.0044	ND	0.0028	ND	0.0028	ND	0.0028	ND	0.0046
Naphthalene	9.9		ND	0.31	ND	1.2	ND	0.2	ND	0.0044	ND	0.0028	ND	0.0028	ND	0.0028	ND	0.0046
EPH (MADEP-EPH-04-1.1)																		
C9-C18 Aliphatics					1500		ND	11										
C19-C36 Aliphatics					3100		24											
C11-C22 Aromatics					5600		37											
Target PAHs																		
Acenaphthene					0.91		ND	0.11	0.24		ND	0.2	6.3		ND	0.18	ND	0.39
Acenaphthylene					ND	0.58	ND	0.11	ND	0.23	0.21		1.1		ND	0.18	ND	0.39
Anthracene					ND	0.58	0.2		0.56		0.55		12		0.45		0.7	
Benzo(a)anthracene					ND	0.58	0.88		2.5		1.9		24		1.2		2.2	
Benzo(a)pyrene					ND	0.58	0.83		2.5		1.7		21		1.1		1.9	
Benzo(b)fluoranthene					ND	0.58	1.1		3.1		2.2		28		1.3		2.7	
Benzo(g,h,i)perylene					ND	0.58	0.54		1.3		0.98		8.4		0.84		1.1	
Benzo(k)fluoranthene					ND	0.58	0.4		1.3		0.91		8.9		0.55		1.1	
Chrysene					ND	0.58	0.95		2.5		2.1		23		1.2		2.2	
Dibenz(a,h)anthracene					ND	0.58	0.16		0.4		0.32		3.5		ND	0.18	ND	0.39
Dibenzofuran									ND	0.45	ND	0.4	5.9		ND	0.36	ND	0.78
Di-n-butylphthalate									ND	0.45	ND	0.4	0.44		ND	0.36	ND	0.78
Fluoranthene					ND	0.58	1.5		4.7		3.8		63		3.1		4.5	
Fluorene					2.3		ND	0.11	ND	0.23	ND	0.2	5.9		ND	0.18	ND	0.39
Indeno(1,2,3-cd)pyrene					ND	0.58	0.57		1.4		1		8.2		0.76		1.1	
2-Methylnaphthalene					ND	0.58	ND	0.11	ND	0.23	ND	0.2	3.1		ND	0.18	ND	0.39
m/p-Methylphenol									ND	0.45	ND	0.4	0.44		ND	0.36	ND	0.78
Naphthalene					ND	0.58	ND	0.11	ND	0.23	ND	0.2	4.6		ND	0.18	ND	0.78
Phenanthrene					ND	0.58	0.83		2.3		2.4		70		2.2		3.2	
Pyrene					11		1.5		5		4.1		56		3.2		4.4	
Metals																		
Arsenic									8.4		10		7.6		ND	2.6	ND	2.9
Barium									84		150		250		17		53	
Cadmium									0.65		0.65		3.1		0.46		0.37	
Chromium									6.9		27		13		8.3		13	
Lead	26		410						74		310		1700		29		130	
Mercury									0.32		0.4		3.5		0.046		0.035	
Total Petroleum Hydrocarbons									900		280		910		120		210	
Polychlorinated Biphenyls									ND	0.13	ND	0.12	ND	0.11	ND	0.11	ND	0.11

All Soil Data
Former BELD Property
44 Allen Street
Braintree, Massachusetts

Sample ID: Sample Date: Depth: ANALYTES	Min	Max	Samples	Number Samples	Mean	Location of Max Detected
VPH (MADEP-VPH-04-1.1)						
C5-C8 Aliphatics	790	790	1	4	206.175	TP-1
C9-C10 Aromatics	91	440	2	4	135.3	TP-1
C9-C12 Aliphatics	96	500	2	4	151.55	TP-1
	0	ND	0	0	NA	ND
Target VOCs	0	ND	0	0	NA	ND
Benzene	1.4	1.4	1	9	0.17515	TP-1
Ethylbenzene	12	12	1	9	1.35292778	TP-1
Methyl-tert-butyl ether	0	ND	0	9	NCC	ND
Naphthalene	9.9	9.9	1	9	1.19596667	TP-1
	0	ND	0	0	NA	ND
EPH (MADEP-EPH-04-1.1)	0	ND	0	0	NA	ND
C9-C18 Aliphatics	1500	1500	1	2	752.75	TP-4
C19-C36 Aliphatics	24	3100	2	2	1562	TP-4
C11-C22 Aromatics	37	5600	2	2	2818.5	TP-4
	0	ND	0	0	NA	ND
Target PAHs	0	ND	0	0	NA	ND
Acenaphthene	0.24	6.3	3	7	1.12714286	TP-9
Acenaphthylene	0.21	1.1	2	7	0.29357143	TP-9
Anthracene	0.2	12	6	7	2.10714286	TP-9
Benzo(a)anthracene	0.88	24	6	7	4.71	TP-9
Benzo(a)pyrene	0.83	21	6	7	4.18857143	TP-9
Benzo(b)fluoranthene	1.1	28	6	7	5.52714286	TP-9
Benzo(g,h,i)perylene	0.54	8.4	6	7	1.92142857	TP-9
Benzo(k)fluoranthene	0.4	8.9	6	7	1.92142857	TP-9
Chrysene	0.95	23	6	7	4.60571429	TP-9
Dibenz(a,h)anthracene	0.16	3.5	4	7	0.70785714	TP-9
Dibenzofuran	5.9	5.9	1	5	1.379	TP-9
Di-n-butylphthalate	0.44	0.44	1	5	0.287	TP-9
Fluoranthene	1.5	63	6	7	11.5557143	TP-9
Fluorene	2.3	5.9	2	7	1.25071429	TP-9
Indeno(1,2,3-cd)pyrene	0.57	8.2	6	7	1.90285714	TP-9
2-Methylnaphthalene	3.1	3.1	1	7	0.56357143	TP-9
m/p-Methylphenol	0.44	0.44	1	5	0.287	TP-9
Naphthalene	4.6	4.6	1	7	0.80571429	TP-9
Phenanthrene	0.83	70	6	7	11.6028571	TP-9
Pyrene	1.5	56	7	7	12.1714286	TP-9
	0	ND	0	0	NA	ND
Metals	0	ND	0	0	NA	ND
Arsenic	7.6	10	3	5	5.75	TP-8
Barium	17	250	5	5	110.8	TP-9
Cadmium	0.37	3.1	5	5	1.046	TP-9
Chromium	6.9	27	5	5	13.64	TP-8
Lead	26	1700	7	7	382.714286	TP-9
Mercury	0.04	3.5	5	5	0.8602	TP-9
	0	ND	0	0	NA	ND
Total Petroleum Hydrocarbons	120	910	5	5	484	TP-9
Polychlorinated Biphenyls	0	ND	0	5	NCC	ND

Surface Soil Data
Former BELD Property
44 Allen Street
Braintree, Massachusetts

Sample ID:	TP-4		TP-8		TP-9		TP-10	
Sample Date:	2/2/16		1/29/16		1/29/16		1/29/16	
Depth:	2-5'		0-3'		0-3'		0-3'	
ANALYTES	*Result*	*MDL*	*Result*	*MDL*	*Result*	*MDL*	*Result*	*MDL*
VPH (MADEP-VPH-04-1.1)								
C5-C8 Aliphatics	ND	49						
C9-C10 Aromatics	91							
C9-C12 Aliphatics	96							
Target VOCs								
Benzene	ND	0.24	ND	0.0014	ND	0.0014	ND	0.0014
Ethylbenzene	ND	0.24	ND	0.0014	ND	0.0014	ND	0.0014
Methyl-tert-butyl ether	ND	0.24	ND	0.0028	ND	0.0028	ND	0.0028
Naphthalene	ND	1.2	ND	0.0028	ND	0.0028	ND	0.0028
EPH (MADEP-EPH-04-1.1)								
C9-C18 Aliphatics	1500							
C19-C36 Aliphatics	3100							
C11-C22 Aromatics	5600							
Target PAHs								
Acenaphthene	0.91		ND	0.2	6.3		ND	0.18
Acenaphthylene	ND	0.58	0.21		1.1		ND	0.18
Anthracene	ND	0.58	0.55		12		0.45	
Benzo(a)anthracene	ND	0.58	1.9		24		1.2	
Benzo(a)pyrene	ND	0.58	1.7		21		1.1	
Benzo(b)fluoranthene	ND	0.58	2.2		28		1.3	
Benzo(g,h,i)perylene	ND	0.58	0.98		8.4		0.84	
Benzo(k)fluoranthene	ND	0.58	0.91		8.9		0.55	
Chrysene	ND	0.58	2.1		23		1.2	
Dibenz(a,h)anthracene	ND	0.58	0.32		3.5		ND	0.18
Dibenzofuran			ND	0.4	5.9		ND	0.36
Di-n-butylphthalate			ND	0.4	0.44		ND	0.36
Fluoranthene	ND	0.58	3.8		63		3.1	
Fluorene	2.3		ND	0.2	5.9		ND	0.18
Indeno(1,2,3-cd)pyrene	ND	0.58	1		8.2		0.76	
2-Methylnaphthalene	ND	0.58	ND	0.2	3.1		ND	0.18
m/p-Methylphenol			ND	0.4	0.44		ND	0.36
Naphthalene	ND	0.58	ND	0.2	4.6		ND	0.18
Phenanthrene	ND	0.58	2.4		70		2.2	
Pyrene	11		4.1		56		3.2	
Metals								
Arsenic			10		7.6		ND	2.6
Barium			150		250		17	
Cadmium			0.65		3.1		0.46	
Chromium			27		13		8.3	
Lead			310		1700		29	
Mercury			0.4		3.5		0.046	
Total Petroleum Hydrocarbons			280		910		120	
Polychlorinated Biphenyls			ND	0.12	ND	0.11	ND	0.11

Surface Soil Data
Former BELD Property
44 Allen Street
Braintree, Massachusetts

Sample ID: Sample Date: Depth: ANALYTES	Min	Max	Samples	Number Samples	Mean	Location of Max Detected
VPH (MADEP-VPH-04-1.1)						
C5-C8 Aliphatics	0	ND	0	1	NCC	ND
C9-C10 Aromatics	91	91	1	1	91	TP-4
C9-C12 Aliphatics	96	96	1	1	96	TP-4
	0	ND	0	0	NA	ND
Target VOCs	0	ND	0	0	NA	ND
Benzene	0	ND	0	4	NCC	ND
Ethylbenzene	0	ND	0	4	NCC	ND
Methyl-tert-butyl ether	0	ND	0	4	NCC	ND
Naphthalene	0	ND	0	4	NCC	ND
	0	ND	0	0	NA	ND
EPH (MADEP-EPH-04-1.1)	0	ND	0	0	NA	ND
C9-C18 Aliphatics	1500	1500	1	1	1500	TP-4
C19-C36 Aliphatics	3100	3100	1	1	3100	TP-4
C11-C22 Aromatics	5600	5600	1	1	5600	TP-4
	0	ND	0	0	NA	ND
Target PAHs	0	ND	0	0	NA	ND
Acenaphthene	0.91	6.3	2	4	1.85	TP-9
Acenaphthylene	0.21	1.1	2	4	0.4225	TP-9
Anthracene	0.45	12	3	4	3.3225	TP-9
Benzo(a)anthracene	1.2	24	3	4	6.8475	TP-9
Benzo(a)pyrene	1.1	21	3	4	6.0225	TP-9
Benzo(b)fluoranthene	1.3	28	3	4	7.9475	TP-9
Benzo(g,h,i)perylene	0.84	8.4	3	4	2.6275	TP-9
Benzo(k)fluoranthene	0.55	8.9	3	4	2.6625	TP-9
Chrysene	1.2	23	3	4	6.6475	TP-9
Dibenz(a,h)anthracene	0.32	3.5	2	4	1.05	TP-9
Dibenzofuran	5.9	5.9	1	3	2.09333333	TP-9
Di-n-butylphthalate	0.44	0.44	1	3	0.27333333	TP-9
Fluoranthene	3.1	63	3	4	17.5475	TP-9
Fluorene	2.3	5.9	2	4	2.0975	TP-9
Indeno(1,2,3-cd)pyrene	0.76	8.2	3	4	2.5625	TP-9
2-Methylnaphthalene	3.1	3.1	1	4	0.895	TP-9
m/p-Methylphenol	0.44	0.44	1	3	0.27333333	TP-9
Naphthalene	4.6	4.6	1	4	1.27	TP-9
Phenanthrene	2.2	70	3	4	18.7225	TP-9
Pyrene	3.2	56	4	4	18.575	TP-9
	0	ND	0	0	NA	ND
Metals	0	ND	0	0	NA	ND
Arsenic	7.6	10	2	3	6.3	TP-8
Barium	17	250	3	3	139	TP-9
Cadmium	0.46	3.1	3	3	1.40333333	TP-9
Chromium	8.3	27	3	3	16.1	TP-8
Lead	29	1700	3	3	679.666667	TP-9
Mercury	0.05	3.5	3	3	1.31533333	TP-9
	0	ND	0	0	NA	ND
Total Petroleum Hydrocarbons	120	910	3	3	436.666667	TP-9
Polychlorinated Biphenyls	0	ND	0	3	NCC	ND

ATTACHMENT B

Method 3 Risk Assessment for Resident Exposed to Chemicals in Soil - Shortform 2012 (sf12rs)

Index

Tab	
EPCs	Table RS-1: Select chemicals and enter Exposure Point Concentrations (EPCs). Estimated risks are shown to the right.
	Table RS-2: Produce risk. Select chemical and enter EPCs.
C Eq	Table RS-3: Equations to calculate cancer risks
cNC Eq	Table RS-4: Equations to calculate chronic noncancer risks
scNC Eq	Table RS-5: Equations to calculate subchronic noncancer risks
Exp	Table RS-6: Definitions and exposure factors
Produce	Table RS-7: Equations to calculate produce ingestion rate
Chem	Table RS-8: Chemical-specific data
Cyanide	Table RS-9: Cyanide Calculations

Spreadsheets designed by Andrew Friedmann, MassDEP
Questions and Comments may be addressed to:
Lydia Thompson
Massachusetts Department of Environmental Protection
Office of Research and Standards
One Winter Street
Boston, MA 02108 USA
Telephone: (617) 556-1165
Fax: (617) 556-1006
Email: Lydia.Thompson@state.ma.us

Resident - Soil: Table RS-1
Exposure Point Concentration (EPC)
Based on Resident Ages 1-31 (Cancer), 1-8 (Chronic Noncancer), and 1-2 (Subchronic Noncancer)

ShortForm Version 10-12
Vlookup Versionv0315

ELCR (all chemicals) = 8.6E-06
Chronic HI (all chemicals) = 1E+00
Subchronic HI (all chemicals) = 2E+00

Do not insert or delete any rows
Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material	EPC (mg/kg)	$ELCR_{ingestion}$	$ELCR_{dermal}$	Derm & Ing $ELCR_{total}$	Chronic HQ_{ing}	Chronic HQ_{derm}	Derm & Ing HQ_{total}	Subchronic HQ_{ing}	Subchronic HQ_{derm}	Derm & Ing HQ_{total}	
ALIPHATICS C5 to C8	2.1E+02				1.2E-02	2.1E-02	3.4E-02	3.4E-03	4.0E-03	7.5E-03	
AROMATICS C9 to C10	1.4E+02				1.1E-02	1.9E-02	3.0E-02	3.0E-03	3.5E-03	6.5E-03	
ALIPHATICS C9 to C12	1.5E+02				3.7E-03	6.3E-03	9.9E-03	1.0E-03	1.2E-03	2.2E-03	
BENZENE	1.8E-01	3.6E-09	1.1E-09	4.7E-09	1.1E-04	2.7E-05	1.3E-04	1.2E-04	2.0E-05	1.4E-04	
ETHYLBENZENE	1.4E+00				6.6E-05	1.7E-05	8.2E-05	1.8E-04	3.2E-05	2.1E-04	
NAPHTHALENE	1.2E+00				4.3E-05	1.2E-04	1.7E-04	1.2E-05	2.3E-05	3.5E-05	
ALIPHATICS C9 to C18	7.5E+02				1.8E-02	3.1E-02	4.9E-02	5.0E-03	5.9E-03	1.1E-02	
ALIPHATICS C19 to C36	1.6E+03				1.9E-03	3.2E-03	5.1E-03	1.7E-03	2.0E-03	3.8E-03	
AROMATICS C11 to C22	2.8E+03				6.8E-02	1.9E-01	2.6E-01	1.9E-02	3.7E-02	5.5E-02	
ACENAPHTHENE	1.1E+00				1.4E-05	3.9E-05	5.2E-05	1.1E-05	2.2E-05	3.3E-05	
ACENAPHTHYLENE	2.9E-01				7.1E-06	2.0E-05	2.7E-05	2.0E-06	3.8E-06	5.8E-06	
ANTHRACENE	2.1E+00				5.1E-06	1.4E-05	2.0E-05	4.2E-06	8.2E-06	1.2E-05	
BENZO(a)ANTHRACENE	4.7E+00	3.9E-07	2.7E-07	6.5E-07	1.1E-04	6.5E-05	1.8E-04	3.1E-05	1.2E-05	4.4E-05	
BENZO(a)PYRENE	4.2E+00	3.4E-06	2.4E-06	5.8E-06	1.0E-04	5.8E-05	1.6E-04	2.8E-05	1.1E-05	3.9E-05	
BENZO(b)FLUORANTHENE	5.5E+00	4.5E-07	3.1E-07	7.7E-07	1.3E-04	7.6E-05	2.1E-04	3.7E-05	1.4E-05	5.1E-05	
BENZO(g,h,i)PERYLENE	1.9E+00				4.7E-05	1.3E-04	1.8E-04	1.3E-05	2.5E-05	3.8E-05	
BENZO(k)FLUORANTHENE	1.9E+00	1.6E-08	1.1E-08	2.7E-08	4.7E-05	2.6E-05	7.3E-05	1.3E-05	5.0E-06	1.8E-05	
CHRYSENE	4.6E+00	3.8E-08	2.6E-08	6.4E-08	1.1E-04	6.3E-05	1.7E-04	3.1E-05	1.2E-05	4.3E-05	
DIBENZO(a,h)ANTHRACENE	7.1E-01	5.8E-07	4.0E-07	9.8E-07	1.7E-05	9.7E-06	2.7E-05	4.7E-06	1.8E-06	6.6E-06	
FLUORANTHENE	1.2E+01				2.1E-04	6.0E-04	8.1E-04	2.3E-04	4.5E-04	6.8E-04	
FLUORENE	1.3E+00				2.3E-05	6.4E-05	8.7E-05	6.3E-06	1.2E-05	1.8E-05	
INDENO(1,2,3-cd)PYRENE	1.9E+00	1.6E-07	1.1E-07	2.6E-07	4.6E-05	2.6E-05	7.2E-05	1.3E-05	4.9E-06	1.8E-05	
METHYLNAPHTHALENE, 2-	5.6E-01				1.0E-04	2.9E-04	3.9E-04	2.8E-04	5.5E-04	8.3E-04	
PHENANTHRENE	1.2E+01				2.8E-04	8.0E-04	1.1E-03	7.7E-05	1.5E-04	2.3E-04	
PYRENE	1.2E+01				2.9E-04	8.4E-04	1.1E-03	8.1E-05	1.6E-04	2.4E-04	
BARIUM	1.1E+02				1.3E-03	1.1E-03	2.5E-03	1.1E-02	6.2E-03	1.7E-02	
CADMIUM	1.0E+00				2.5E-03	4.3E-04	3.0E-03	7.0E-03	8.2E-04	7.8E-03	
LEAD	3.8E+02				6.2E-01	6.3E-02	6.8E-01	1.7E+00	1.2E-01	1.8E+00	**Note! Lead IH HQ limit is 1, not 10.**
MERCURY	8.6E-01				3.5E-03	5.9E-03	9.4E-03	9.6E-03	1.1E-02	2.1E-02	

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Resident - Soil: Table RS-1
Exposure Point Concentration (EPC)
Based on Resident Ages 1-31 (Cancer), 1-8 (Chronic Noncancer), and 1-2 (Subchronic Noncancer)

ShortForm Version 10-12
Vlookup Versionv0315

ELCR (all chemicals) = 1.2E-05
Chronic HI (all chemicals) = 2E+00
Subchronic HI (all chemicals) = 3E+00

Do not insert or delete any rows
Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material	EPC (mg/kg)	$ELCR_{ingestion}$	$ELCR_{dermal}$	Derm & Ing $ELCR_{total}$	Chronic HQ_{ing}	Chronic HQ_{derm}	Derm & Ing HQ_{total}	Subchronic HQ_{ing}	Subchronic HQ_{derm}	Derm & Ing HQ_{total}	
AROMATICS C9 to C10	9.1E+01				7.4E-03	1.3E-02	2.0E-02	2.0E-03	2.4E-03	4.4E-03	
ALIPHATICS C9 to C12	9.6E+01				2.3E-03	4.0E-03	6.3E-03	6.4E-04	7.5E-04	1.4E-03	
ALIPHATICS C9 to C18	1.5E+03				3.6E-02	6.2E-02	9.8E-02	1.0E-02	1.2E-02	2.2E-02	
ALIPHATICS C19 to C36	3.1E+03				3.8E-03	6.4E-03	1.0E-02	3.4E-03	4.0E-03	7.5E-03	
AROMATICS C11 to C22	5.6E+03				1.4E-01	3.8E-01	5.2E-01	3.7E-02	7.3E-02	1.1E-01	
ACENAPHTHENE	1.9E+00				2.2E-05	6.4E-05	8.6E-05	1.9E-05	3.6E-05	5.5E-05	
ACENAPHTHYLENE	4.2E-01				1.0E-05	2.9E-05	3.9E-05	2.8E-06	5.5E-06	8.3E-06	
ANTHRACENE	3.3E+00				8.1E-06	2.3E-05	3.1E-05	6.7E-06	1.3E-05	2.0E-05	
BENZO(a)ANTHRACENE	6.8E+00	5.6E-07	3.9E-07	9.5E-07	1.7E-04	9.4E-05	2.6E-04	4.6E-05	1.8E-05	6.3E-05	
BENZO(a)PYRENE	6.0E+00	4.9E-06	3.4E-06	8.3E-06	1.5E-04	8.3E-05	2.3E-04	4.0E-05	1.6E-05	5.6E-05	
BENZO(b)FLUORANTHENE	7.9E+00	6.5E-07	4.5E-07	1.1E-06	1.9E-04	1.1E-04	3.0E-04	5.3E-05	2.1E-05	7.4E-05	
BENZO(g,h,i)PERYLENE	2.6E+00				6.4E-05	1.8E-04	2.4E-04	1.8E-05	3.4E-05	5.2E-05	
BENZO(k)FLUORANTHENE	2.7E+00	2.2E-08	1.5E-08	3.7E-08	6.5E-05	3.7E-05	1.0E-04	1.8E-05	6.9E-06	2.5E-05	
CHRYSENE	6.6E+00	5.4E-08	3.8E-08	9.2E-08	1.6E-04	9.1E-05	2.5E-04	4.4E-05	1.7E-05	6.2E-05	
DIBENZO(a,h)ANTHRACENE	1.1E+00	8.6E-07	5.9E-07	1.5E-06	2.5E-05	1.4E-05	4.0E-05	7.0E-06	2.7E-06	9.7E-06	
FLUORANTHENE	1.8E+01				3.2E-04	9.0E-04	1.2E-03	3.5E-04	6.8E-04	1.0E-03	
FLUORENE	2.1E+00				3.8E-05	1.1E-04	1.5E-04	1.0E-05	2.0E-05	3.1E-05	
INDENO(1,2,3-cd)PYRENE	2.6E+00	2.1E-07	1.5E-07	3.6E-07	6.2E-05	3.5E-05	9.7E-05	1.7E-05	6.7E-06	2.4E-05	
METHYLNAPHTHALENE, 2-	9.0E-01				1.6E-04	4.6E-04	6.2E-04	4.5E-04	8.7E-04	1.3E-03	
NAPHTHALENE	1.3E+00				4.6E-05	1.3E-04	1.8E-04	1.3E-05	2.5E-05	3.7E-05	
PHENANTHRENE	1.9E+01				4.5E-04	1.3E-03	1.7E-03	1.2E-04	2.4E-04	3.7E-04	
PYRENE	1.9E+01				4.5E-04	1.3E-03	1.7E-03	1.2E-04	2.4E-04	3.7E-04	
BARIUM	1.4E+02				1.7E-03	1.4E-03	3.1E-03	1.3E-02	7.7E-03	2.1E-02	
CADMIUM	1.4E+00				3.4E-03	5.8E-04	4.0E-03	9.4E-03	1.1E-03	1.0E-02	
LEAD	6.8E+02				1.1E+00	1.1E-01	1.2E+00	3.0E+00	2.1E-01	3.2E+00	**Note! Lead IH HQ limit is 1, not 10.**
MERCURY	1.3E+00				5.3E-03	9.0E-03	1.4E-02	1.5E-02	1.7E-02	3.2E-02	

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Resident - Soil: Table RS-2
Exposure Point Concentration (EPC)
Based on Resident Ages 1-31 (Cancer), 1-8 (Chronic Noncancer), and 1-2 (Subchronic Noncancer)

Vlookup Versionv0315

ELCR (all chemicals) =
Chronic HI (all chemicals) = 5E+01
Subchronic HI (all chemicals) = 7E+01

*Vegetable uptake is informational only and NOT included in totals on EPC tab.

Do not insert or delete any rows

Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material	EPC (mg/kg)	Chronic		Subchronic
		$ELCR_{vegetable*}$	$HQ_{vegetable*}$	$HQ_{vegetable*}$
BARIUM	1.4E+02			
CADMIUM	1.4E+00		3.8E+00	5.4E+00
LEAD	6.8E+02		4.8E+01	6.9E+01
MERCURY	1.3E+00			

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Resident - Soil: Table RS-3

Equations to Calculate Cancer Risk for Resident (Age 1-31 years)

Cancer Risk from Ingestion

$$ELCR_{ing} = LADD_{ing(1\text{-}31)} * CSF$$

$$LADD_{ing\ (1\text{-}31)} = LADD_{ing\ (1\text{-}8)} + LADD_{ing\ (8\text{-}15)} + LADD_{ing\ (15\text{-}31)}$$

$$LADD_{ing\ (age\ group\ x)} = \frac{[OHM]_{soil} * IR_x * RAF_{c\text{-}ing} * EF_{ing} * ED * EP_x * C}{BW_x * AP_{lifetime}}$$

Cancer Risk from Dermal Absorption

$$ELCR_{derm} = LADD_{derm} * CSF$$

$$LADD_{derm\ (1\text{-}31)} = LADD_{derm\ (1\text{-}8)} + LADD_{derm\ (8\text{-}15)} + LADD_{derm\ (15\text{-}31)}$$

$$LADD_{derm(age\ group\ x)} = \frac{[OHM]_{soil} * SA_x * RAF_{c\text{-}derm} * SAF_x * EF_{derm} * ED * EP_x * C}{BW_x * AP_{lifetime}}$$

Cancer Risk from Homegrown Produce

$$ELCR_{produce} = LADD_{produce(1\text{-}31)} * CSF$$

$$LADD_{produce(1\text{-}31)} = LADD_{produce(1\text{-}8)} + LADD_{produce(8\text{-}15)} + LADD_{produce(15\text{-}31)}$$

$$LADD_{produce(age\ x)} = \frac{[OHM_{soil}] * PUF * PIR_x * RAF_{produce} * EF_{produce} * ED * EP_x * C}{BW_x * AP_{lifetime}}$$

Vlookup Versionv0315

Parameter	Value	Units
CSF	OHM specific	$(mg/kg\text{-}day)^{-1}$
LADD	age/OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
$IR_{(1\text{-}8)}$	100	mg/day
$IR_{(8\text{-}15)}$	50	mg/day
$IR_{(15\text{-}31)}$	50	mg/day
$PIR_{(1\text{-}8)}$	12,099	mg/day
$PIR_{(8\text{-}15)}$	17,809	mg/day
$PIR_{(15\text{-}31)}$	24,420	mg/day
$RAF_{c\text{-}ing}$	OHM specific	dimensionless
$RAF_{c\text{-}derm}$	OHM specific	dimensionless
$RAF_{c\text{-}produce}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.412	event/day
$EF_{produce}$	1.00	event/day
ED	1	day/event
$EP_{(1\text{-}8)}$	7	years
$EP_{(8\text{-}15)}$	7	years
$EP_{(15\text{-}31)}$	16	years
C	0.000001	kg/mg
$BW_{(1\text{-}8)}$	17.0	kg
$BW_{(8\text{-}15)}$	39.9	kg
$BW_{(15\text{-}31)}$	58.7	kg
$AP_{(lifetime)}$	70	years
$SA_{(1\text{-}8)}$	2431	cm^2 / day
$SA_{(8\text{-}15)}$	4427	cm^2 / day
$SA_{(15\text{-}31)}$	5653	cm^2 / day
$SAF_{(1\text{-}8)}$	0.35	mg/cm^2
$SAF_{(8\text{-}15)}$	0.14	mg/cm^2
$SAF_{(15\text{-}31)}$	0.13	mg/cm^2
PUF	OHM specific	$(mg/mg)(mg/mg)^{-1}$

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Resident - Soil: Table RS-4
Equations to Calculate Chronic Noncancer Risk for Resident Child (Age 1-8 years)

Vlookup Versionv0315

Chronic Noncancer Risk from Ingestion

$$HQ_{ing} = \frac{ADD_{ing}}{RfD}$$

$$ADD_{ing} = \frac{[OHM]_{soil} * IR * RAF_{nc\text{-}ing} * EF_{ing} * ED * EP * C}{BW * AP}$$

Chronic Noncancer Risk from Dermal Absorption

$$HQ_{derm} = \frac{ADD_{ing,derm}}{RfD}$$

$$ADD_{derm} = \frac{[OHM]_{soil} * SA * RAF_{nc\text{-}derm} * SAF * EF_{derm} * ED * EP * C}{BW * AP}$$

Chronic Noncancer Risk from Homegrown Produce

$$HQ_{produce} = \frac{ADD_{produce}}{RfD}$$

$$ADD_{produce} = \frac{[OHM_{soil}] * PUF * PIR * RAF_{produce} * EF_{produce} * ED * EP * C}{BW * AP}$$

Parameter	Value	Units
RfD	OHM specific	mg/kg-day
ADD	OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
IR	100	mg/day
PIR	12,099	mg/day
$RAF_{nc\text{-}ing}$	OHM specific	dimensionless
$RAF_{nc\text{-}derm}$	OHM specific	dimensionless
$RAF_{nc\text{-}produce}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.412	event/day
$EF_{produce}$	1.00	event/day
ED	1	day/event
EP	7	years
C	0.000001	kg/mg
BW	17.0	kg
AP	7	year
SA	2431	cm^2 / day
SAF	0.35	mg/cm^2
PUF	OHM specific	$(mg/mg)(mg/mg)^{-1}$

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Resident - Soil: Table RS-5

Equations to Calculate Subchronic Noncancer Risk for Resident Child (Age 1-2 years)

Vlookup Versionv0315

Subchronic Noncancer Risk from Ingestion

$$HQ_{ing} = \frac{ADD_{ing}}{RfD_{subchronic}}$$

$$ADD_{ing} = \frac{[OHM]_{soil} * IR * RAF_{nc\text{-}ing} * EF_{ing} * ED * EP * C}{BW * AP}$$

Subchronic Noncancer Risk from Dermal Absorption

$$HQ_{derm} = \frac{ADD_{derm}}{RfD_{subchronic}}$$

$$ADD_{derm} = \frac{[OHM]_{soil} * SA * RAF_{nc\text{-}derm} * SAF * EF_{derm} * ED * EP * C}{BW * AP}$$

Subchronic Noncancer Risk from Homegrown Produce

$$HQ_{produce} = \frac{ADD_{produce}}{RfD_{subchronic}}$$

$$ADD_{produce} = \frac{[OHM_{soil}] * PUF * PIR * RAF_{produce} * EF_{produce} * ED * EP * C}{BW * AP}$$

Parameter	Value	Units
RfD	OHM specific	mg/kg-day
ADD	OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
IR	100	mg/day
PIR	10,900	mg/day
$RAF_{nc\text{-}ing}$	OHM specific	dimensionless
$RAF_{nc\text{-}derm}$	OHM specific	dimensionless
$RAF_{nc\text{-}produce}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.714	event/day
$EF_{produce}$	1.00	event/day
ED	1	day/event
EP	0.577	years
C	0.000001	kg/mg
BW	10.7	kg
AP	0.577	year
SA	1670	cm^2 / day
SAF	0.35	mg/cm^2
PUF	OHM specific	$(mg/mg)(mg/mg)^{-1}$

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Resident - Soil: Table RS-6
Definitions and Exposure Factors

Vlookup Versionv0315

Parameter	Value	Units	Notes
ELCR - Excess Lifetime Cancer Risk	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
CSF - Cancer Slope Factor	chemical specific	$(mg/kg\text{-}day)^{-1}$	see Table RS-7
LADD - Lifetime Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
LADE - Lifetime Average Daily Exposure	chemical specific	$\mu g/m^3$	
HQ - Hazard Quotient	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
RfD - Reference Dose	chemical specific	mg/kg-day	see Table RS-7
ADD - Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
ADE - Average Daily Exposure	chemical specific	mg/m^3	
EPC - Exposure Point Concentration	chemical specific	mg/kg	
PUF - Plant Uptake Factor	chemical specific	$(mg/mg)(mg/mg)^{-1}$	See Table RS-7; $(mg_{OHM}/mg_{plant})/(mg_{OHM}/mg_{soil})^{-1}$
$IR_{(1-2)}$ - Soil Ingestion Rate for age group 1-2	100	mg/day	MADEP. 2002. Technical Update: Calculation of an Enhanced Soil Ingestion Rate. (http://www.mass.gov/dep/ors/orspubs.htm)
$IR_{(1-8)}$ - Soil Ingestion Rate for age group 1-8	100	mg/day	Ibid
$IR_{(8-15)}$ - Soil Ingestion Rate for age group 8-15	50	mg/day	Ibid
$IR_{(15-31)}$ - Soil Ingestion Rate for age group 15-31	50	mg/day	Ibid
$PIR_{(1-2)}$ = Produce Ingestion Rate for age group 1-2	10,900	mg/day	see Table RS-6
$PIR_{(1-8)}$ = Produce Ingestion Rate for age group 1-8	12,099	mg/day	see Table RS-6
$PIR_{(8-15)}$ = Produce Ingestion Rate for age group 8-15	17,809	mg/day	Ibid
$PIR_{(15-31)}$ = Produce Ingestion Rate for age group 15-31	24,420	mg/day	Ibid
RAF_c - Relative Absorption Factor for Cancer Effects	chemical specific	dimensionless	
$EF_{subchronic}$ - Exposure Frequency for subchronic ingestion or dermal exposure	0.714	event/day	5 days/week
$EF_{chronic}$ - Exposure Frequency for chronic ingestion or dermal exposure	0.412	event/day	5 days/week, 30 weeks/year
EF_{cancer} - Exposure Frequency for cancer, ingestion or dermal exposure	0.412	event/day	5 days/week, 30 weeks/year
$EF_{produce}$ - Exposure Frequency for produce ingestion, cancer and noncancer	1.00	event/day	
ED - Exposure Duration	1	day/event	
$EP_{(1-2)}$ - Exposure Period for age group 1-2	0.577	years	30 weeks
$EP_{(1-8)}$ - Exposure Period for age group 1-8	7	years	
$EP_{(8-15)}$ - Exposure Period for age group 8-15	7	years	
$EP_{(15-31)}$ - Exposure Period for age group 15-31	16	years	
$BW_{(1-2)}$ - Body Weight for age group 1-2	10.7	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, females.
$BW_{(1-8)}$ - Body Weight for age group 1-8	17.0	kg	Ibid
$BW_{(8-15)}$ - Body Weight for age group 8-15	39.9	kg	Ibid
$BW_{(15-31)}$ - Body Weight for age group 15-31	58.7	kg	Ibid
$AP_{subchronic}$ - Averaging Period for subchronic noncancer	0.577	years	30 weeks
$AP_{chronic}$ - Averaging Period for chronic noncancer	7	years	
AP_{cancer} - Averaging Period for lifetime	70	years	
$SA_{(1-2)}$ - Surface Area for age group 1-2	1670	cm^2 / day	50th percentile of face (1/3 head), forearms, hands, lower legs, and feet for females
$SA_{(1-8)}$ - Surface Area for age group 1-8	2431	cm^2 / day	MADEP. 1995. Guidance for Disposal Site Risk Characterization. Appendix Table B-2. Ibid
$SA_{(8-15)}$ - Surface Area for age group 8-15	4427	cm^2 / day	Ibid
$SA_{(15-31)}$ - Surface Area for age group 15-31	5653	cm^2 / day	Ibid
$SAF_{(1-2)}$. Surface Adherence Factor for age group 1-2	0.35	mg/cm^2	All SAFs developed for ShortForm according to procedure outlined in MA DEP Technical
$SAF_{(1-8)}$. Surface Adherence Factor for age group 1-8	0.35	mg/cm^2	Update:Weighted Skin-Soil Adherence Factors, April 2002
$SAF_{(8-15)}$ - Surface Adherence Factor for age group 8-15	0.14	mg/cm^2	
$SAF_{(15-31)}$ - Surface Adherence Factor for age group 15-31	0.13	mg/cm^2	

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Resident - Soil: Table RS-7
Homegrown Produce Ingestion Rate

Vlookup Versionv0315

Data on mean produce ingestion rates (wet weight, ww) in the Northeast was obtained from the 1994-1996 Continuing Survey of Food Intakes by Individuals (USDA). Data for both genders were used for children under 6, while data for males was used for individuals 6 and older. The mean ingestion rates presented in the survey represent the arithmetic average of all individuals surveyed, regardless of whether or not they had consumed the produce item (e.g., an individual that did not consume the produce item was assigned a rate of 0 g/day). To determine the mean ingestion rate for individuals who ate each produce item, the ingestion rate for all individuals (consumers and nonconsumers) was divided by the percentage of individuals who ate the item (Table RS-7A). These mean ingestion rates for the produce consumers were summed to determine the total produce ingestion rate for each age-group and converted to dry weight assuming the produce items were all 90% water.

To convert mean ingestion rates for the age-groups studied in the survey to age-groups used in risk calculations, each age-group ingestion rate from the survey (i.e., 1 - 2 year olds, 3 - 5 year olds, 6 - 11 year olds, 12 - 19 year olds, and 20 - 39 year olds) was weighted according to the number of years spent in the risk calculation age group (i.e., 1 - 8 year olds, 8 - 15 year olds, and 15 - 31 year olds) (Table RS-7B). It was assumed that 25% of produce ingested was home-grown (Table RS-7C).

Table RS-7

	White Potatoes			Dark-green vegetables			Deep-yellow vegetables		
Age-groups studied in survey	Ingestion Rate for All g/d (ww)	% of individuals that consumed item.	Ingestion Rate for Consumers g/d (ww)	Ingestion Rate for All g/d (ww)	% of individuals that consumed item.	Ingestion Rate for Consumers g/d (ww)	Ingestion Rate for All g/d (ww)	% of individuals that consumed item.	Ingestion Rate for Consumers g/d (ww)
1-2	28	40.3	69.5	6	10.1	59.4	5	12.7	39.4
3-5	30	37.1	80.9	5	6.5	76.9	7	12.7	55.1
6-11	47	44.2	106.3	6	9.1	65.9	2	8.5	23.5
12-19	59	40.3	146.4	2	2.3	87.0	11	15.8	69.6
20-39	76	45.1	168.5	25	14.7	170.1	4	5.7	70.2

	Tomatoes			Lettuce			Green Beans		
Age-groups studied in survey	Ingestion Rate for All g/d (ww)	% of individuals that consumed item.	Ingestion Rate for Consumers g/d (ww)	Ingestion Rate for All g/d (ww)	% of individuals that consumed item.	Ingestion Rate for Consumers g/d (ww)	Ingestion Rate for All g/d (ww)	% of individuals that consumed item.	Ingestion Rate for Consumers g/d (ww)
1-2	10	27.9	35.8	1	6	16.7	7	12.1	57.9
3-5	10	37.1	27.0	4	14	28.6	3	5.7	52.6
6-11	20	42	47.6	8	14.9	53.7	1	2	50.0
12-19	29	45.2	64.2	19	28.7	66.2	2	2.4	83.3
20-39	48	50.9	94.3	18	29.6	60.8	4	3.7	108.1

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Table RS-7a (continued)

Age-groups studied in survey	Corn, Green peas, Lima beans: Ingestion Rate for All g/d (ww)	Corn, Green peas, Lima beans: % of individuals that consumed item.	Corn, Green peas, Lima beans: Ingestion Rate for Consumers g/d (ww)	Melons, berries: Ingestion Rate for All g/d (ww)	Melons, berries: % of individuals that consumed item.	Melons, berries: Ingestion Rate for Consumers g/d (ww)	Totals Wet Weight WWI g/day	Totals Dry Weight DWI g/day
1-2	12	15	80.0	7	9	77.8	436.4	43.6
3-5	14	21.7	64.5	14	11.6	120.7	506.3	50.6
6-11	9	13.6	66.2	5	5.9	84.7	498.0	49.8
12-19	14	9.9	141.4	17	5	340.0	998.1	99.8
20-39	12	7.3	164.4	6	4.5	133.3	969.7	97.0

Table RS-7B

Age-groups studied in survey	Years spent in age-group 1-8 year old	Years spent in age-group 8-15 year old	Years spent in age-group 15-31 year old
1-2	2		
3-5	3		
6-11	2	4	
12-19		3	4
20-39			12
	7	7	16

Table RS-7C

	Produce Intake, dry weight: Child 1-2 years g/day	Child 1-8 years g/day	Child 8-15 years g/day	Adult 15-31 g/day
All Produce:	43.6	48.4	71.2	97.7
Homegrown:	10.9	12.1	17.8	24.4

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Resident - Soil: Table RS-8
Chemical-Specific Data

Vlookup Versionv0315

Oil or Hazardous Material	CSF $(mg/kg\text{-}day)^{-1}$	$RAF_{c\text{-}ing}$	$RAF_{c\text{-}derm}$	$RAF_{c\text{-}prod}$	Chronic RfD mg/kg-day	Subchronic RfD mg/kg-day	Chronic $RAF_{nc\text{-}ing}$	Chronic $RAF_{nc\text{-}derm}$	Subchronic $RAF_{nc\text{-}ing}$	Subchronic $RAF_{nc\text{-}derm}$	$RAF_{nc\text{-}prod}$	PUF
ALIPHATICS C5 to					4.0E-02	4.0E-01	1	0.2	1	0.2		
AROMATICS C9 to					3.0E-02	3.0E-01	1	0.2	1	0.2		
ALIPHATICS C9 to C					1.0E-01	1.0E+00	1	0.2	1	0.2		
BENZENE	5.5E-02	1.00	0.03		4.0E-03	1.0E-02	1	0.03	1	0.03		
ETHYLBENZENE					5.0E-02	5.0E-02	1	0.03	1	0.03		
NAPHTHALENE					2.0E-02	2.0E-01	0.3	0.1	0.3	0.1		
ALIPHATICS C9 to C					1.0E-01	1.0E+00	1	0.2	1	0.2		
ALIPHATICS C19 to					2.0E+00	6.0E+00	1	0.2	1	0.2		
AROMATICS C11 to					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
ACENAPHTHENE					6.0E-02	2.0E-01	0.3	0.1	0.3	0.1		
ACENAPHTHYLENE					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
ANTHRACENE					3.0E-01	1.0E+00	0.3	0.1	0.3	0.1		
BENZO(a)ANTHRACENI	7.3E-01	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
BENZO(a)PYRENE	7.3E+00	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
BENZO(b)FLUORANTHE	7.3E-01	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
BENZO(g,h,i)PERYLENE					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
BENZO(k)FLUORANTHE	7.3E-02	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
CHRYSENE	7.3E-02	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
DIBENZO(a,h)ANTHRAC	7.3E+00	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
FLUORANTHENE					4.0E-02	1.0E-01	0.3	0.1	0.3	0.1		
FLUORENE					4.0E-02	4.0E-01	0.3	0.1	0.3	0.1		
INDENO(1,2,3-cd)PYREI	7.3E-01	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
METHYLNAPHTHALENE					4.0E-03	4.0E-03	0.3	0.1	0.3	0.1		
PHENANTHRENE					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
PYRENE					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
BARIUM					2.0E-01	7.0E-02	1	0.1	1	0.1		
CADMIUM					5.0E-04	5.0E-04	0.5	0.01	0.5	0.01	1	1.9
LEAD					7.5E-04	7.5E-04	0.5	0.006	0.5	0.006	0.5	0.15
MERCURY					3.0E-04	3.0E-04	0.5	0.1	0.5	0.1		

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Resident - Soil: Table RS-9
Cyanide Calculations

The soil cyanide concentration limit set to protect a child resident against an acute, potentially lethal one-time dose of cyanide from incidental ingestion of contaminated soil is 100 mg/kg soil. This is the concentration of available cyanide in soil below which acute human health effects would not be expected following a one-time exposure. This soil concentration is calculated using the equation below with a pica-type soil ingestion of 1000 mg_{soil} and an available cyanide dose limit of 0.01 $mg/kg_{body\ weight}$.

MassDEP's guidance on evaluating the risk from a one-time cyanide dose considers cyanide's potentially lethal effects as well as information on cyanide metabolism:

> Cyanides are detoxified rapidly by the body, and a large acute dose which overwhelms the detoxification mechanism is potentially more toxic than the same dose distributed over a period of hours. (MassDEP *Background Documentation for the Development of an Available Cyanide Benchmark Concentration* , originally dated October 1992, Modified August 1998)

Assessment of a potential one-time dose requires an estimate of the maximum soil concentration the receptor could contact at any one time. The average soil concentration within a typical exposure area will underestimate the potential one-time dose. Therefore, to assess the acute risk of a one-time potentially lethal dose, the EPC for cyanide should be a conservative estimate of the maximum soil concentration.

The residential soil concentration limit to protect against adverse effects from an acute (one-time) exposure to cyanide is 100 mg/kg.

Concentration Calculation for Cyanide

$$\text{Concentration} = \frac{\text{HQ x Acute Dose Limit x BW}}{\text{IR x RAF x Conversion Factor}}$$

Parameter	Value	Units
HQ (Hazard Quotient)	1	(unitless)
Acute Dose Limit	0.01	mg avail. CN/ kg BW
BW (Body Weight) $_{1-2}$	10.7	kg
IR $_{(1\text{-time reasonable max})}$	1000	mg
Conversion Factor	1.0E-06	kg soil / mg soil
RAF	1	(unitless)

The toxicological basis for estimating an allowable one-time dose is documented in MassDEP's 1992 *Background Documentation for the Development of an "Available Cyanide" Benchmark Concentration,* which is published at: http://www.mass.gov/eea/docs/dep/toxics/stypes/dscyanide.pdf

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

ATTACHMENT C

Method 3 Risk Assessment for Employee Exposed to Chemicals in Soil - Shortform 2012 (sf12em)

Index

Tab	
EPCs	Table EM-1: Select chemicals and enter Exposure Point Concentrations (EPCs). Estimated risks are shown to the right.
C Eq	Table EM-2: Equations to calculate cancer risks
cNC Eq	Table EM-3: Equations to calculate chronic noncancer risks
scNC Eq	Table EM-4: Equations to calculate subchronic noncancer risks
Exp	Table EM-5: Definitions and exposure factors
Produce	Table EM-6: Equations to calculate produce ingestion rate
Chem	Table EM-7: Chemical-specific data
Cyanide	Table EM-8: Cyanide Calculations

Spreadsheets designed by Andrew Friedmann, MassDEP

Modified for employee receptor.

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Employee - Soil: Table EM-1A - All Soil
Exposure Point Concentration (EPC)
Based on Employee

ShortForm Version 10-12

Vlookup Version v1012

ELCR (all chemicals) = 8E-06
Chronic HI (all chemicals) = 9E-02

Do not insert or delete any rows
Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material	EPC (mg/kg)	$ELCR_{ingestion}$	$ELCR_{dermal}$	Derm & Ing $ELCR_{total}$	Chronic HQ_{ing}	Chronic HQ_{derm}	Derm & Ing HQ_{total}
ALIPHATICS C5 to C8	2.1E+02				1.4E-03	5.8E-04	2.0E-03
AROMATICS C9 to C10	1.4E+02				1.2E-03	5.1E-04	1.7E-03
ALIPHATICS C9 to C12	1.5E+02				4.1E-04	1.7E-04	5.8E-04
BENZENE	1.8E-01	6.6E-12	6.3E-11	6.9E-11	1.2E-05	7.4E-07	1.3E-05
ETHYLBENZENE	1.4E+00				7.3E-06	4.6E-07	7.8E-06
NAPHTHALENE	1.2E+00				4.8E-06	3.4E-06	8.2E-06
ALIPHATICS C9 to C18	7.5E+02				2.0E-03	8.5E-04	2.9E-03
ALIPHATICS C19 to C36	1.6E+03				2.1E-04	8.8E-05	3.0E-04
AROMATICS C11 to C22	2.8E+03				7.6E-03	5.3E-03	1.3E-02
ACENAPHTHENE	1.1E+00				1.5E-06	1.1E-06	2.6E-06
ACENAPHTHYLENE	2.9E-01				7.9E-07	5.5E-07	1.3E-06
ANTHRACENE	2.1E+00				5.7E-07	4.0E-07	9.6E-07
BENZO(a)ANTHRACENE	4.7E+00	7.5E-06	1.5E-08	7.5E-06	1.3E-05	1.8E-06	1.4E-05
BENZO(a)PYRENE	4.2E+00		1.3E-07	1.3E-07	1.1E-05	1.6E-06	1.3E-05
BENZO(b)FLUORANTHENE	5.5E+00	7.6E-11	1.8E-08	1.8E-08	1.5E-05	2.1E-06	1.7E-05
BENZO(g,h,i)PERYLENE	1.9E+00				5.2E-06	3.6E-06	8.8E-06
BENZO(k)FLUORANTHENE	1.9E+00		6.1E-10	6.1E-10	5.2E-06	7.2E-07	5.9E-06
CHRYSENE	4.6E+00		1.5E-09	1.5E-09	1.2E-05	1.7E-06	1.4E-05
DIBENZO(a,h)ANTHRACENE	7.1E-01		2.2E-08	2.2E-08	1.9E-06	2.7E-07	2.2E-06
FLUORANTHENE	1.2E+01				2.3E-05	1.6E-05	4.0E-05
FLUORENE	1.3E+00				2.5E-06	1.8E-06	4.3E-06
INDENO(1,2,3-cd)PYRENE	1.9E+00		6.0E-09	6.0E-09	5.1E-06	7.1E-07	5.9E-06
METHYLNAPHTHALENE, 2-	5.6E-01				1.1E-05	7.9E-06	1.9E-05
PHENANTHRENE	1.2E+01				3.1E-05	2.2E-05	5.3E-05
PYRENE	1.2E+01				3.3E-05	2.3E-05	5.6E-05
BARIUM	1.1E+02				1.5E-04	3.1E-05	1.8E-04
CADMIUM	1.0E+00				5.6E-04	1.2E-05	5.8E-04
LEAD	3.8E+02				6.9E-02	1.7E-03	7.1E-02
MERCURY	8.6E-01				3.9E-04	1.6E-04	5.5E-04

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Employee - Soil: Table EM-1B - Surface Soil
Exposure Point Concentration (EPC)
Based on Employee

ShortForm Version 10-12

Vlookup Version v1012

ELCR (all chemicals) = 2E-06
Chronic HI (all chemicals) = 2E-01

Do not insert or delete any rows
Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material	EPC (mg/kg)	$ELCR_{ingestion}$	$ELCR_{dermal}$	Derm & Ing $ELCR_{total}$	Chronic HQ_{ing}	Chronic HQ_{derm}	Derm & Ing HQ_{total}
AROMATICS C9 to C10	9.1E+01				8.2E-04	3.4E-04	1.2E-03
ALIPHATICS C9 to C12	9.6E+01				2.6E-04	1.1E-04	3.7E-04
ALIPHATICS C9 to C18	1.5E+03				4.1E-03	1.7E-03	5.7E-03
ALIPHATICS C19 to C36	3.1E+03				4.2E-04	1.7E-04	5.9E-04
AROMATICS C11 to C22	5.6E+03				1.5E-02	1.1E-02	2.6E-02
ACENAPHTHENE	1.9E+00				2.5E-06	1.7E-06	4.2E-06
ACENAPHTHYLENE	4.2E-01				1.1E-06	7.9E-07	1.9E-06
ANTHRACENE	3.3E+00				9.0E-07	6.2E-07	1.5E-06
BENZO(a)ANTHRACENE	6.8E+00	1.9E-07	2.2E-08	2.1E-07	1.8E-05	2.6E-06	2.1E-05
BENZO(a)PYRENE	6.0E+00	7.4E-07	1.9E-07	9.3E-07	1.6E-05	2.3E-06	1.9E-05
BENZO(b)FLUORANTHENE	7.9E+00	2.5E-07	2.5E-08	2.8E-07	2.1E-05	3.0E-06	2.4E-05
BENZO(g,h,i)PERYLENE	2.6E+00				7.1E-06	4.9E-06	1.2E-05
BENZO(k)FLUORANTHENE	2.7E+00	4.2E-07	8.4E-10	4.2E-07	7.2E-06	1.0E-06	8.2E-06
CHRYSENE	6.6E+00		2.1E-09	2.1E-09	1.8E-05	2.5E-06	2.0E-05
DIBENZO(a,h)ANTHRACENE	1.1E+00	1.4E-10	3.3E-08	3.3E-08	2.8E-06	3.9E-07	3.2E-06
FLUORANTHENE	1.8E+01				3.6E-05	2.5E-05	6.0E-05
FLUORENE	2.1E+00				4.2E-06	3.0E-06	7.2E-06
INDENO(1,2,3-cd)PYRENE	2.6E+00		8.1E-09	8.1E-09	6.9E-06	9.6E-07	7.9E-06
METHYLNAPHTHALENE, 2-	9.0E-01				1.8E-05	1.3E-05	3.1E-05
NAPHTHALENE	1.3E+00				5.1E-06	3.6E-06	8.7E-06
PHENANTHRENE	1.9E+01				5.1E-05	3.5E-05	8.6E-05
PYRENE	1.9E+01				5.0E-05	3.5E-05	8.5E-05
BARIUM	1.4E+02				1.9E-04	3.9E-05	2.3E-04
CADMIUM	1.4E+00				7.6E-04	1.6E-05	7.7E-04
LEAD	6.8E+02				1.2E-01	3.1E-03	1.3E-01
MERCURY	1.3E+00				5.9E-04	2.5E-04	8.4E-04

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Employee - Soil: Table EM-2

Equations to Calculate Cancer Risk for Employee

Cancer Risk from Ingestion

$$ELCR_{ing} = LADD_{ing} * CSF$$

$$LADD_{ing} = \frac{[OHM]_{soil} * IR * RAF_{c\text{-}ing} * EF_{ing} * ED * EP * C}{BW * AP_{lifetime}}$$

Cancer Risk from Dermal Absorption

$$ELCR_{derm} = LADD_{derm} * CSF$$

$$LADD_{derm} = \frac{[OHM]_{soil} * SA * RAF_{c\text{-}derm} * SAF * EF_{derm} * ED * EP * C}{BW * AP_{lifetime}}$$

Vlookup Version v1012

Parameter	Value	Units
CSF	OHM specific	$(mg/kg\text{-}day)^{-1}$
LADD	OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
IR	50	mg/day
$RAF_{c\text{-}ing}$	OHM specific	dimensionless
$RAF_{c\text{-}derm}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.33	event/day
ED	1	day/event
EP	27	years
C	0.000001	kg/mg
BW	61.1	kg
$AP_{(lifetime)}$	70	years
SA	3473	cm^{-} / day
SAF	0.03	mg/cm^{2}

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Employee - Soil: Table EM-3
Equations to Calculate Chronic Noncancer Risk for Employee

Vlookup Version v1012

Chronic Noncancer Risk from Ingestion

$$HQ_{ing} = \frac{ADD_{ing}}{RfD}$$

$$ADD_{ing} = \frac{[OHM]_{soil} * IR * RAF_{nc\text{-}ing} * EF_{ing} * ED * EP * C}{BW * AP}$$

Chronic Noncancer Risk from Dermal Absorption

$$HQ_{derm} = \frac{ADD_{ing,derm}}{RfD}$$

$$ADD_{derm} = \frac{[OHM]_{soil} * SA * RAF_{nc\text{-}derm} * SAF * EF_{derm} * ED * EP * C}{BW * AP}$$

Parameter	Value	Units
RfD	OHM specific	mg/kg-day
ADD	OHM specific	mg/kg-day
$[OHM]_{soil}$	OHM specific	mg/kg
IR	50	mg/day
$RAF_{nc\text{-}ing}$	OHM specific	dimensionless
$RAF_{nc\text{-}derm}$	OHM specific	dimensionless
$EF_{ing,derm}$	0.33	event/day
ED	1	day/event
EP	27	years
C	0.000001	kg/mg
BW	61.1	kg
AP	27	year
SA	3473	cm^2 / day
SAF	0.03	mg/cm^2

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Employee - Soil: Table EM-4
Definitions and Exposure Factors

Vlookup Version v1012

Parameter	Value	Units	Notes
ELCR - Excess Lifetime Cancer Risk	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
CSF - Cancer Slope Factor	chemical specific	$(mg/kg\text{-}day)^{-1}$	see Table EM-5
LADD - Lifetime Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
LADE - Lifetime Average Daily Exposure	chemical specific	$\mu g/m^3$	
HQ - Hazard Quotient	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
RfD - Reference Dose	chemical specific	mg/kg-day	see Table EM-5
ADD - Average Daily Dose	chemical specific	mg/kg-day	Pathway specific
ADE - Average Daily Exposure	chemical specific	mg/m^3	
EPC - Exposure Point Concentration	chemical specific	mg/kg	
IR - Soil Ingestion Rate	50	mg/day	MADEP. 2002. Technical Update: Calculation of an Enhanced Soil Ingestion Rate.
RAF_c - Relative Absorption Factor for Cancer Effects	chemical specific	dimensionless	(http://www.mass.gov/dep/ors/orspubs.htm)
$EF_{chronic}$ - Exposure Frequency for chronic ingestion or dermal exposure	0.33	event/day	4 days/week, 30 weeks/year
EF_{cancer} - Exposure Frequency for cancer, ingestion or dermal exposure	0.33	event/day	4 days/week, 30 weeks/year
ED - Exposure Duration	1	day/event	
EP - Exposure Period	27	years	
BW - Body Weight	61.1	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7
$AP_{chronic}$ - Averaging Period for chronic noncancer	27	years	
AP_{cancer} - Averaging Period for lifetime	70	years	
SA - Surface Area	3473	cm^2 / day	50th percentile of face, forearms, hands, lower legs and feet for females. MADEP 1995 Guidance for Disposal Site Risk Characterization, Table B-2.
SAF - Surface Adherence Factor	0.03	mg/cm^2	SAF developed for ShortForm according to procedure outlined in MA DEP Technical Update:

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Employee - Soil: Table EM-5
Chemical-Specific Data

Vlookup Version v1012

Oil or Hazardous Material	CSF (mg/kg-day)$^{-1}$	$RAF_{c\text{-}ing}$	$RAF_{c\text{-}derm}$	$RAF_{c\text{-}prod}$	Chronic RfD mg/kg-day	Subchronic RfD mg/kg-day	Chronic $RAF_{nc\text{-}ing}$	Chronic $RAF_{nc\text{-}derm}$	Subchronic $RAF_{nc\text{-}ing}$	Subchronic $RAF_{nc\text{-}derm}$	$RAF_{nc\text{-}prod}$	PUF
ALIPHATICS C5 to C8					4.0E-02	4.0E-01	1	0.2	1	0.2		
AROMATICS C9 to C10					3.0E-02	3.0E-01	1	0.2	1	0.2		
ALIPHATICS C9 to C12					1.0E-01	1.0E+00	1	0.2	1	0.2		
BENZENE	5.5E-02	1.00	0.03		4.0E-03	1.0E-02	1	0.03	1	0.03		
ETHYLBENZENE					5.0E-02	5.0E-02	1	0.03	1	0.03		
NAPHTHALENE					2.0E-02	2.0E-01	0.3	0.1	0.3	0.1		
ALIPHATICS C9 to C18					1.0E-01	1.0E+00	1	0.2	1	0.2		
ALIPHATICS C19 to C36					2.0E+00	6.0E+00	1	0.2	1	0.2		
AROMATICS C11 to C22					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
ACENAPHTHENE					6.0E-02	2.0E-01	0.3	0.1	0.3	0.1		
ACENAPHTHYLENE					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
ANTHRACENE					3.0E-01	1.0E+00	0.3	0.1	0.3	0.1		
BENZO(a)ANTHRACENE	7.3E-01	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
BENZO(a)PYRENE	7.3E+00	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
BENZO(b)FLUORANTHENE	7.3E-01	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
BENZO(g,h,i)PERYLENE					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
BENZO(k)FLUORANTHENE	7.3E-02	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
CHRYSENE	7.3E-02	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
DIBENZO(a,h)ANTHRACENE	7.3E+00	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
FLUORANTHENE					4.0E-02	4.0E-01	0.3	0.1	0.3	0.1		
FLUORENE					4.0E-02	4.0E-01	0.3	0.1	0.3	0.1		
INDENO(1,2,3-cd)PYRENE	7.3E-01	0.30	0.02		3.0E-02	3.0E-01	0.3	0.02	0.3	0.02		
METHYLNAPHTHALENE, 2-					4.0E-03	4.0E-03	0.3	0.1	0.3	0.1		
PHENANTHRENE					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
PYRENE					3.0E-02	3.0E-01	0.3	0.1	0.3	0.1		
BARIUM					2.0E-01	7.0E-02	1	0.1	1	0.1		
CADMIUM					5.0E-04	5.0E-04	1	0.01	1	0.01	1	1.9
LEAD					7.5E-04	7.5E-04	0.5	0.006	0.5	0.006	0.5	0.15

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

ATTACHMENT D

Method 3 Risk Assessment for Chemicals in Soil - Construction Worker Shortform 2012 (sf12cw)

Index

Spreadsheets designed by Andrew Friedmann, MassDEP
Questions and Comments may be addressed to:
Lydia Thompson
Massachusetts Department of Environmental Protection
Office of Research and Standards
One Winter Street
Boston, MA 02108 USA
Telephone: (617) 556-1165
Fax: (617) 556-1006
Email: Lydia.Thompson@state.ma.us

Construction Worker - Soil: Table CW-1
Exposure Point Concentration (EPC) and Risk
Based on Construction Worker 18-25 years of age

ShortForm Version 10-12
Vlookup Version v0315

ELCR (all chemicals) = 2.1E-07
HI (all chemicals) = 4.1E-01

****Do not insert or delete any rows****
Click on empty cell below and select OHM using arrow.

Oil or Hazardous Material (OHM)	EPC (mg/kg)	ELCR ingestion	ELCR dermal	ELCR inhalation GI	ELCR inhalation pulmonary	$ELCR_{total}$	Subchronic HQ_{ing}	Subchronic HQ_{derm}	Subchronic HQ_{inh-GI}	Subchronic HQ_{inh}	HQ_{total}
ALIPHATICS C5 to C8	2.1E+02						6.3E-04	1.3E-03	1.6E-05	3.8E-05	2.0E-03
AROMATICS C9 to C10	1.4E+02						5.6E-04	1.1E-03	1.4E-05	1.0E-05	1.7E-03
ALIPHATICS C9 to C12	1.5E+02						1.9E-04	3.8E-04	4.8E-06	9.4E-06	5.8E-04
BENZENE	1.8E-01	8.5E-11	2.6E-11	2.2E-12	3.6E-13	1.1E-10	2.2E-05	6.5E-06	5.6E-07	6.5E-07	2.9E-05
ETHYLBENZENE	1.4E+00						3.3E-05	1.0E-05	8.6E-07	5.6E-09	4.4E-05
NAPHTHALENE	1.2E+00						2.2E-06	7.4E-06	5.7E-08	1.5E-05	2.5E-05
ALIPHATICS C9 to C18	7.5E+02						9.3E-04	1.9E-03	2.4E-05	4.7E-05	2.9E-03
ALIPHATICS C19 to C36	1.6E+03						3.2E-04	6.5E-04	8.3E-06		9.7E-04
AROMATICS C11 to C22	2.8E+03						3.5E-03	1.2E-02	9.0E-05	2.1E-04	1.5E-02
ACENAPHTHENE	1.1E+00						2.1E-06	7.0E-06	5.4E-08	8.4E-08	9.2E-06
ACENAPHTHYLENE	2.9E-01						3.6E-07	1.2E-06	9.4E-09	2.2E-08	1.6E-06
ANTHRACENE	2.1E+00						7.8E-07	2.6E-06	2.0E-08	1.6E-07	3.6E-06
BENZO(a)ANTHRACENE	4.7E+00	9.0E-09	6.1E-09	2.3E-10	2.6E-10	1.6E-08	5.8E-06	3.9E-06	1.5E-07	3.5E-07	1.0E-05
BENZO(a)PYRENE	4.2E+00	8.0E-08	5.4E-08	2.1E-09	2.3E-09	1.4E-07	5.2E-06	3.5E-06	1.3E-07	3.1E-07	9.1E-06
BENZO(b)FLUORANTHENE	5.5E+00	1.1E-08	7.1E-09	2.8E-10	3.1E-10	1.8E-08	6.8E-06	4.6E-06	1.8E-07	4.1E-07	1.2E-05
BENZO(g,h,i)PERYLENE	1.9E+00						2.4E-06	7.9E-06	6.1E-08	1.4E-07	1.1E-05
BENZO(k)FLUORANTHENE	1.9E+00	3.7E-10	2.5E-10	9.6E-12	1.1E-11	6.4E-10	2.4E-06	1.6E-06	6.1E-08	1.4E-07	4.2E-06
CHRYSENE	4.6E+00	8.8E-10	5.9E-10	2.3E-11	2.5E-11	1.5E-09	5.7E-06	3.8E-06	1.5E-07	3.4E-07	1.0E-05
DIBENZO(a,h)ANTHRACENE	7.1E-01	1.4E-08	9.1E-09	3.5E-10	3.9E-10	2.3E-08	8.7E-07	5.9E-07	2.3E-08	5.3E-08	1.5E-06
FLUORANTHENE	1.2E+01						4.3E-05	1.4E-04	1.1E-06	8.6E-07	1.9E-04
FLUORENE	1.3E+00						1.2E-06	3.9E-06	3.0E-08	9.3E-08	5.2E-06
INDENO(1,2,3-cd)PYRENE	1.9E+00	3.7E-09	2.5E-09	9.5E-11	1.1E-10	6.3E-09	2.3E-06	1.6E-06	6.1E-08	1.4E-07	4.1E-06
METHYLNAPHTHALENE, 2-	5.6E-01						5.2E-05	1.7E-04	1.3E-06	4.2E-08	2.3E-04
PHENANTHRENE	1.2E+01						1.4E-05	4.8E-05	3.7E-07	8.6E-07	6.4E-05
PYRENE	1.2E+01						1.5E-05	5.0E-05	3.9E-07	9.1E-07	6.7E-05
BARIUM	1.1E+02						1.9E-03	2.0E-03	5.1E-05	8.3E-04	4.8E-03
CADMIUM	1.0E+00				5.0E-10	5.0E-10	1.3E-03	2.6E-04	3.3E-05	1.9E-03	3.5E-03
LEAD	3.8E+02						3.1E-01	3.8E-02	8.1E-03	1.4E-02	3.7E-01
MERCURY	8.6E-01						1.8E-03	3.6E-03	4.6E-05	1.1E-04	5.5E-03

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Construction Worker - Soil: Table CW-2

Equations to Calculate Cancer Risk for Construction Worker

Vlookup Version v0315

Cancer Risk from Ingestion

$$ELCR_{ing} = LADD_{ing} * CSF_{oral}$$

$$LADD_{ing} = \frac{EPC * IR * RAF_{c\text{-}ing} * EF * ED_{ing} * EP * C1}{BW * AP_{lifetime}}$$

Cancer Risk from Dermal Absorption

$$ELCR_{derm} = LADD_{derm} * CSF_{oral}$$

$$LADD_{derm} = \frac{EPC * SA * AF * RAF_{c\text{-}derm} * EF * ED_{derm} * EP * C1}{BW * AP_{lifetime}}$$

Cancer Risk from Particulate Inhalation - Gastrointestinal Absorption

$$ELCR_{inh\text{-}GI} = LADD_{inh\text{-}GI} * CSF_{oral}$$

$$LADD_{inh\text{-}GI} = \frac{EPC * RCAF_{inh\text{-}gi} * PM_{10} * VR_{work} * RAF_{c\text{-}ing} * EF * ED_{inh} * EP * C2 * C3 * C4}{BW * AP_{lifetime}}$$

Cancer Risk from Particulate Inhalation - Pulmonary Absorption

$$ELCR_{inh} = LADD_{inh} * CSF_{inhalation}$$

$$LADD = \frac{EPC * RCAF_{inh} * PM_{10} * VR_{work} * RAF_{c\text{-}inh} * EF * ED_{inh} * EP * C2 * C3 * C4}{BW * AP_{lifetime}}$$

Parameter	Value	Units
CSF	OHM-specific	$(mg/kg\text{-}day)^{-1}$
LADD	age/OHM-specific	mg/kg-day
EPC	OHM-specific	mg/kg
IR	100	mg/day
$RAF_{c\text{-}ing}$	OHM-specific	dimensionless
$RAF_{c\text{-}derm}$	OHM-specific	dimensionless
$RAF_{c\text{-}inh}$	OHM-specific	dimensionless
EF	0.714	event/day
$ED_{ing\ \&\ derm}$	1	day/event
ED_{inh}	0.333	day/event
EP	182	days
C1	1.0E-06	kg/mg
C2	1.0E-09	kg/µg
C3	1440	min/days
C4	1.0E-03	m^3/L
BW	58.0	kg
$AP_{(lifetime)}$	25,550	days
VR_{work}	60	L/min
AF	0.29	mg/cm^2
SA	3473	cm^2/day
$RCAF_{inh\text{-}gi}$	1.5	dimensionless
$RCAF_{inh}$	0.5	dimensionless
PM_{10}	60	$\mu g/m^3$

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Construction Worker - Soil: Table CW-3

Equations to Calculate Noncancer Risk for Construction Worker

Vlookup Version v0315

Noncancer Risk from Ingestion

$$HQ_{ing} = \frac{ADD_{ing}}{RfD_{oral\text{-}subchronic}}$$

$$ADD_{ing} = \frac{EPC * IR * RAF_{nc\text{-}ing} * EF * ED_{ing} * EP * C1}{BW * AP_{noncancer}}$$

Noncancer Risk from Dermal Absorption

$$HQ_{derm} = \frac{ADD_{derm}}{RfD_{oral\text{-}subchronic}}$$

$$ADD_{dermal} = \frac{EPC * SA * AF * RAF_{nc\text{-}derm} * EF * ED_{dermal} * EP * C1}{BW * AP_{noncancer}}$$

Noncancer Risk from Particulate Inhalation - Gastrointestinal Absorption

$$HQ_{inh\text{-}GI} = \frac{ADD_{inh\text{-}GI}}{RfD_{oral\text{-}subchronic}}$$

$$ADD_{inh\text{-}GI} = \frac{EPC * RCAF_{inh\text{-}gi} * PM_{10} * VR_{work} * RAF_{nc\text{-}ing} * EF * ED_{inh} * EP * C2 * C3 * C4}{BW * AP_{noncancer}}$$

Noncancer Risk from Particulate Inhalation - Pulmonary Absorption

$$HQ_{inh} = \frac{ADD}{RfD_{inhalation\text{-}subchronic}}$$

$$ADD_{inh} = \frac{EPC_{soil} * RCAF_{inh} * PM_{10} * VR_{work} * RAF_{nc\text{-}inh} * EF * ED_{inh} * EP * C2 * C3 * C4}{BW * AP_{noncancer}}$$

Parameter	Value	Units
RfD	OHM-specific	mg/kg-day
ADD	OHM-specific	mg/kg-day
EPC	OHM-specific	mg/kg
IR	100	mg/day
$RAF_{nc\text{-}ing}$	OHM-specific	dimensionless
$RAF_{nc\text{-}derm}$	OHM-specific	dimensionless
$RAF_{nc\text{-}inh}$	OHM-specific	dimensionless
EF	0.714	event/day
$ED_{ing\ \&\ derm}$	1	day/event
ED_{inh}	0.333	day/event
EP	182	days
C1	1.0E-06	kg/mg
C2	1.0E-09	kg/µg
C3	1440	min/days
C4	1.0E-03	m^3/L
BW	58.0	kg
$AP_{noncancer}$	182	days
VR_{work}	60	L/min
AF	0.29	mg/cm^2
SA	3473	cm^2/day
$RCAF_{inh\text{-}gi}$	1.5	dimensionless
$RCAF_{inh}$	0.5	dimensionless
PM10	60	$µg/m^3$

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Construction Worker - Soil: Table CW-4
Definitions and Exposure Factors

Vlookup Version v0315

Parameter	Value	Units	Notes
ELCR - Excess Lifetime Cancer Risk	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
HI - Hazard Index	chemical specific	dimensionless	Pathway specific (ing =ingestion, derm=dermal, inh=inhalation)
CSF - Cancer Slope Factor	chemical specific	$(mg/kg\text{-}day)^{-1}$	see Table CW-5.
RfD - Reference Dose	chemical specific	mg/kg-day	see Table CW-5.
LADD - Lifetime Average Daily Dose	chemical specific	mg/kg-day	Pathway specific. See Table CW-2.
ADD - Average Daily Dose	chemical specific	mg/kg-day	Pathway specific. See Table CW-3.
EPC - Exposure Point Concentration	chemical specific	mg/kg	see Table CW-1.
IR - Soil Ingestion Rate	100	mg/day	MADEP. 2002. Technical Update: Calculation of an Enhanced Soil Ingestion Rate. (http://www.mass.gov/dep/ors/orspubs.htm).
RAF_c - Relative Absorption Factor for Cancer Effects	chemical specific	dimensionless	Pathway specific - see Table CW-5.
RAF_{nc} - Relative Absorption Factor for Noncancer Effects	chemical specific	dimensionless	Pathway specific - see Table CW-5.
EF - Exposure Frequency	0.714	event/day	5 events (days) / 7 events (days) in a week; MADEP 1995 Guidance for Disposal Site Risk Characterization pg B-38.
$ED_{ing,derm}$ - Exposure Duration for ingestion or dermal exposure	1	day/event	
ED_{inh} - Exposure Duration for inhalation exposure	0.333	day/event	Represents 8 hours / event.
EP - Exposure Period	182	days	6 months; MADEP 1995 Guidance for Disposal Site Risk Characterization.
BW - Body Weight	58.0	kg	U.S. EPA. 1997. Exposure Factors Handbook. Table 7-7, Females, ages 18 - 25.
$AP_{(lifetime)}$ - Averaging Period for lifetime	25,550	days	Represents 70 years
$AP_{(noncancer)}$ - Averaging Period for noncancer	182	days	6 months; MADEP 1995 Guidance for Disposal Site Risk Characterization.
AF - Adherence Factor	0.29	mg/cm^2	MA DEP. 2002 Technical Update: Weighted Skin-Soil Adherence Factors. (http://www.mass.gov/dep/ors/orspubs.htm)
VR_{work} - Ventilation Rate during work (heavy exertion)	60	L/min	Table B-4 MADEP 1995 Guidance for Disposal Site Risk Characterization.
SA - Surface Area	3473	cm^2/day	MADEP. 1995. Guidance for Disposal Site Risk Characterization. 50th percentile for females. Appendix Table B-2.
$IFAF_{inh\text{-}gi}$ - Ingestion Fraction Adjustment Factor, gastrointestinal	1.5	dimensionless	MADEP 2007. Characterization of Risks Due to Inhalation of Particulates by Construction Workers
$IFAF_{inh}$ - Inhalation Fraction Adjustment Factor, inhalation	0.5	dimensionless	MADEP 2002. Characterization of Risks Due to Inhalation of Particulates by Construction Workers
PM10 - Concentration of PM_{10}	60	$\mu g/m^3$	MADEP 1995 Guidance for Disposal Site Risk Characterization pg B-11

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Construction Worker - Soil: Table CW-5
Chemical-Specific Data

Vlookup Version v0315

Oil or Hazardous Material	Oral CSF $(mg/kg\text{-}day)^{-1}$	$RAF_{c\text{-}ing}$	$RAF_{c\text{-}derm}$	$RAF_{c\text{-}inh}$	Inhalation CSF $(mg/kg\text{-}day)^{-1}$	Subchronic Oral RfD mg/kg-day	Subchronic $RAF_{nc\text{-}ing}$	Subchronic $RAF_{nc\text{-}derm}$	Subchronic $RAF_{nc\text{-}inh}$	Subchronic Inhalation RfD
ALIPHATICS C5 to C8						4.0E-01	1	0.2	1	5.7E-02
AROMATICS C9 to C10						3.0E-01	1	0.2	1	1.4E-01
ALIPHATICS C9 to C12						1.0E+00	1	0.2	1	1.7E-01
BENZENE	5.5E-02	1	0.03	1	2.7E-02	1.0E-02	1	0.03	1	2.9E-03
ETHYLBENZENE						5.0E-02	1	0.03	1	2.6E+00
NAPHTHALENE						2.0E-01	0.3	0.1	1	8.6E-04
ALIPHATICS C9 to C18						1.0E+00	1	0.2	1	1.7E-01
ALIPHATICS C19 to C36						6.0E+00	1	0.2		
AROMATICS C11 to C22						3.0E-01	0.3	0.1	1	1.4E-01
ACENAPHTHENE						2.0E-01	0.3	0.1	1	1.4E-01
ACENAPHTHYLENE						3.0E-01	0.3	0.1	1	1.4E-01
ANTHRACENE						1.0E+00	0.3	0.1	1	1.4E-01
BENZO(a)ANTHRACENE	7.3E-01	0.3	0.02	1	7.3E-01	3.0E-01	0.3	0.02	1	1.4E-01
BENZO(a)PYRENE	7.3E+00	0.3	0.02	1	7.3E+00	3.0E-01	0.3	0.02	1	1.4E-01
BENZO(b)FLUORANTHENE	7.3E-01	0.3	0.02	1	7.3E-01	3.0E-01	0.3	0.02	1	1.4E-01
BENZO(g,h,i)PERYLENE						3.0E-01	0.3	0.1	1	1.4E-01
BENZO(k)FLUORANTHENE	7.3E-02	0.3	0.02	1	7.3E-02	3.0E-01	0.3	0.02	1	1.4E-01
CHRYSENE	7.3E-02	0.3	0.02	1	7.3E-02	3.0E-01	0.3	0.02	1	1.4E-01
DIBENZO(a,h)ANTHRACENE	7.3E+00	0.3	0.02	1	7.3E+00	3.0E-01	0.3	0.02	1	1.4E-01
FLUORANTHENE						1.0E-01	0.3	0.1	1	1.4E-01
FLUORENE						4.0E-01	0.3	0.1	1	1.4E-01
INDENO(1,2,3-cd)PYRENE	7.3E-01	0.3	0.02	1	7.3E-01	3.0E-01	0.3	0.02	1	1.4E-01
METHYLNAPHTHALENE, 2-						4.0E-03	0.3	0.1	1	1.4E-01
PHENANTHRENE						3.0E-01	0.3	0.1	1	1.4E-01
PYRENE						3.0E-01	0.3	0.1	1	1.4E-01
BARIUM						7.0E-02	1	0.1	1	1.4E-03
CADMIUM					6.3E+00	5.0E-04	0.5	0.01	1	5.7E-06
LEAD						7.5E-04	0.5	0.006	1	2.9E-04
MERCURY						3.0E-04	0.5	0.1	1	8.6E-05

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165

Construction Worker - Soil: Table CW-6
Cyanide Calculations

The soil cyanide concentration limit set to protect a construction worker against an acute, potentially lethal one-time dose of cyanide from incidental ingestion of contaminated soil is 12,000 mg/kg_{soil}. This is the concentration of available cyanide in soil below which acute human health effects would not be expected following a one-time exposure. This soil concentration is calculated using the equation below with a one-time soil ingestion estimate of 50 mg_{soil} and an available cyanide dose limit of 0.01 $mg/kg_{body\ weight}$.

MassDEP's guidance on evaluating the risk from a one-time cyanide dose considers cyanide's potentially lethal effects as well as information on cyanide metabolism:

> Cyanides are detoxified rapidly by the body, and a large acute dose which overwhelms the detoxification mechanism is potentially more toxic than the same dose distributed over a period of hours. (MassDEP *Background Documentation for the Development of an Available Cyanide Benchmark Concentration,* originally dated October 1992, Modified August 1998)

Assessment of a potential one-time dose requires an estimate of the maximum soil concentration the trespasser could contact at any one time. The average soil concentration within a typical exposure area will underestimate the potential one-time dose. Therefore, to assess the acute risk of a one-time potentially lethal dose, the EPC for cyanide should be a conservative estimate of the maximum concentration.

The construction worker soil concentration limit to protect against adverse effects from an acute (one-time) exposure to cyanide is 12,000 mg/kg.

Acute Concentration Calculation for Cyanide

$$\text{Concentration} = \frac{\text{HQ x Acute Dose Limit x BW}}{\text{IR x RAF x Conversion Factor}}$$

Parameter	Value	Units
HQ (Hazard Quotient)	1	(unitless)
Acute Dose Limit	0.01	mg avail. CN/ kg BW
BW (Body Weight) $_{11\text{-}12}$	58	kg
IR $_{(1\text{-time reasonable max})}$	50	mg
Conversion Factor	1.0E-06	kg soil / mg soil
RAF	1	(unitless)

The toxicological basis for estimating an allowable one-time dose is documented in MassDEP's 1992 *Background Documentation for the Development of an "Available Cyanide" Benchmark Concentration,* which is published at: http://www.mass.gov/eea/docs/dep/toxics/stypes/dscyanide.pdf

MassDEP ORS
Contact: Lydia Thompson
Lydia.Thompson@state.ma.us
617-556-1165