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APPENDIX A

DERIVATION OF SOIL S-1

**NORMALIZED AVERAGE DAILY SOIL INGESTION RATE
(NADSIR)**

**NORMALIZED AVERAGE DAILY SOIL/SKIN CONTACT RATE
(NADSCR)**

**NORMALIZED LIFETIME AVERAGE DAILY SOIL INGESTION RATE
(NLADSIR)**

**NORMALIZED LIFETIME AVERAGE DAILY SOIL/SKIN CONTACT RATE
(NLADSCR)**

APPENDIX A

DERIVATION OF SOIL S-1 EXPOSURE RATES

1. SOIL INGESTION RATES:

This section describes the development of the soil ingestion rates used to calculate the S-1 soil standards. These values are age specific and normalized to body weight. As a result of the detailed analysis, each age group experiences a slightly different exposure, and the calculated annual average daily soil ingestion rates range between approximately 20 to 60 mg of soil per day. The step-wise process followed in the calculation of the exposure rates is described below.

STEP 1: Ingestion of indoor dust is considered for young children, aged 1 to 6 years. It is assumed that each exposure event consists of the ingestion of the dust/soil covering the surface of one half of one finger. Table A-1 develops soil ingestion rates for these indoor exposures, and this information is used in Step 2.

TABLE A-1

INDOOR-ONLY SOIL INGESTION EXPOSURE						
AGE	Skin Surface Area: 1/2 of One Finger ¹	Dust Adherence ²	Fraction of Finger Dust from Soil ³	Frequency of Mouthing Events ⁴	Hours of Exposure per day	Soil Ingested - INDOORONLY ⁵
years	cm ² /event	mg/cm ²		events/hour	hrs/day	mg soil/day
1 < 2	7.3	0.056	0.8	9	3	28.8
2 < 3	7.7	0.056	0.8	9	7	21.7
3 < 4	9.9	0.056	0.8	9	7	27.9
4 < 5	10.1	0.056	0.8	9	7	28.5
5 < 6	11.1	0.056	0.8	9	7	31.3

1 - The surface area of 1/2 of one finger is assumed to be approximately equal to 1/40 the surface area of both hands. The source of the Surface area information is described in more detail in Table A-5. This value is derived from that table: (Column 2 * Column 3 /100/40).

2 - Hawley, 1985; average dust covering indoor surfaces assumed to be the average dust covering finger.

3 - Hawley, 1985

4 - MA DEQE, 1985

5 - The mass of soil ingested as a result of finger mouthing activities. Example, age 1 < 2:

$$7.3 * 0.056 * 0.8 * 9 * 3 = 8.8 \text{ mg soil/day}$$

STEP 2: An annual average daily soil intake is developed for each age group, as shown in Table A-2. This value is weighted to reflect the relative time spent outdoors where greater exposure to soil is expected. The resulting soil ingestion rates are then used in Step 3.

TABLE A-2

CALCULATION OF AGE-SPECIFIC SOIL INGESTION RATES					
AGE years	SOIL INGESTION RATES * On days Exposed *		FREQUENCY OF EXPOSURE		ANNUAL AVERAGE 365 days
	Indoor Exposure Only ¹ mg soil/d	Indoor & Outdoor Exposure ² mg soil/d	Indoors Only ³ Oct. -> April of 212 days days	Indoors + Outdoors ⁴ May -> Sept. of 153 days	DAILY SOIL INGESTION RATE ⁵ mg soil/d
<1	0	0	0	0	0
1 <2	8.8	100	212	44 + 109 = 153	47.0
2 <3	21.7	100	212	44 + 109 = 153	54.5
3 <4	27.9	100	212	44 + 109 = 153	58.1
4 <5	28.5	100	212	44 + 109 = 153	58.5
5 <6	31.3	100	212	44 + 109 = 153	60.1
6 <7	0	50	0	44 + 109 = 153	21.0
7 <8	0	50	0	44 + 109 = 153	21.0
8 <9	0	50	0	44 + 109 = 153	21.0
9 <10	0	50	0	44 + 109 = 153	21.0
10 <11	0	50	0	44 + 109 = 153	21.0
11 <12	0	50	0	44 + 109 = 153	21.0
12 <13	0	50	0	44 + 109 = 153	21.0
13 <14	0	50	0	44 + 109 = 153	21.0
14 <15	0	50	0	44 + 109 = 153	21.0
15 <16	0	50	0	44 + 109 = 153	21.0
16 <17	0	50	0	44 + 109 = 153	21.0
17 <18	0	50	0	44 + 109 = 153	21.0
18 <25	0	50	0	44 + 109 = 153	21.0
25 <30	0	50	0	44 + 109 = 153	21.0

- 1 - Indoor ONLY Exposures taken from Table A-1.
- 2 - Soil Ingestion Rate on days when BOTH Indoor & Outdoor exposures may occur taken from LaGoy (1987)
- 3 - 212 days is approximately 7 days/week from October through April. No outdoor exposure is assumed to occur during this period.
- 4 - 153 days approximates indoor exposures 2 days/week and outdoor exposures 5 days/week during this period.
- 5 - The average daily soil ingestion rate for this age group, adjusted for the frequency of exposure.
Example, age 1 < 2 years:
$$[(8.8 \text{ mg/d} * 212 \text{ d}) + (100 \text{ mg/d} * 153 \text{ d})] / 365 \text{ d} = 47.0 \text{ mgsoil/day}$$

STEP 3: The soil ingestion rates from Step 2 are normalized to the body weight of each age group and weighted for the number of years in that age group (This is important for ages 18<25 and 25<30). This calculation is presented in Table A-3.

TABLE A-3
CALCULATION OF TIME-WEIGHTED AVERAGE DAILY SOIL
INGESTION EXPOSURES
NORMALIZED TO BODYWEIGHT

AGE	MEDIAN BODY WEIGHT ¹	SOIL INGESTION RATE ²	WEIGHTING FACTOR ³	DAILY SOIL INGESTION RATE FOR THE TIME PERIOD ⁴
years	kg	mg soil/day	years	(mg * yrs)/(kg * d)
< 1	8.5	0	1	0
1 < 2	10.5	47.0	1	4.5
2 < 3	12.6	54.5	1	4.3
3 < 4	14.6	58.1	1	4
4 < 5	16.4	58.5	1	3.6
5 < 6	18.8	60.1	1	3.2
6 < 7	21.0	21.0	1	1
7 < 8	23.5	21.0	1	0.89
8 < 9	27.3	21.0	1	0.77
9 < 10	29.6	21.0	1	0.71
10 < 11	34.3	21.0	1	0.61
11 < 12	40.0	21.0	1	0.53
12 < 13	45.2	21.0	1	0.46
13 < 14	48.6	21.0	1	0.43
14 < 15	52.8	21.0	1	0.40
15 < 16	53.9	21.0	1	0.39
16 < 17	55.3	21.0	1	0.38
17 < 18	58.3	21.0	1	0.36
18 < 25	57.1	21.0	7	2.6
25 < 30	59.9	21.0	5	3.5

- 1 - 50th percentile body weights taken from U.S. EPA, 1989b, pp. 5-43 & 5-45.
2 - Soil Ingestion Rate calculated in Table A-2.
3 - Weighting Factor is equal to the number of years represented by each age group.
4 - The Soil Ingestion Rate Normalized to Body Weight for the specified time period.
Example Calculation, age 1 < 2:

$$[(47.0 \text{ mg soil/d}) * 1 \text{ yr}] / 10.5 \text{ kg} = 4.5 \text{ (mg * yr) / (kg * d)}$$

STEP 4: Finally, these age-specific values are combined to yield the time-weighted, normalized values used to calculate the risk-based concentration for Category S-1 soil. These values are developed in Table A-4, and the results summarized in Table 5-1.

**TABLE A-4
CALCULATION OF THE
NORMALIZED DAILY SOIL INTAKE RATES
USED FOR S-1 STANDARD SETTING**

NONCANCER EFFECTS		CARCINOGENIC EFFECTS	
AGE	DAILY SOIL INGESTION RATE FOR THE TIME PERIOD	AGE	DAILY SOIL INGESTION RATE FOR THE TIME PERIOD
years	(mg * yrs)/(kg * d)	years	(mg * yrs)/(kg * d)
1 < 2	4.5	< 1	0
2 < 3	4.3	1 < 2	4.5
3 < 4	4	2 < 3	4.3
4 < 5	3.6	3 < 4	4
5 < 6	3.2	4 < 5	3.6
6 < 7	1	5 < 6	3.2
7 < 8	0.89	6 < 7	1
		7 < 8	0.89
# Years = 7	SUM: 21.5	8 < 9	0.77
		9 < 10	0.71
		10 < 11	0.61
		11 < 12	0.53
		12 < 13	0.46
		13 < 14	0.43
		14 < 15	0.40
		15 < 16	0.39
		16 < 17	0.38
		17 < 18	0.36
		18 < 25	2.6
		25 < 30	1.8
		Exposure Period = 30 yr	SUM: 31
		AVERAGING PERIOD	
		75 Years	
	Normalized Average Daily Soil Intake Rate:		Normalized Lifetime Average Daily Soil Intake Rate:
	21.5/7 = 3.1 mg soil/(kg*day)		31/75 = 0.41 mg soil/(kg * day)

For the non-cancer risk-based concentration, the averaging period is equal to the exposure period. For cancer risk, the averaging period is a lifetime (75 years), independent of the length of the exposure period (MA DEQE, 1989a).

2. DERMAL CONTACT RATES

This section describes the development of the rates of contact between the soil and the receptor's skin. Absorption through the skin is potentially an important route of exposure which depends, in part, on the exposed skin surface area. Since surface area varies by age, the soil/dermal contact rate would be expected to vary by age as well. The values are age-specific and are normalized to body weight. The exposure model used to quantify the dermal contact exposure pathway assumes that some contact will occur in the home during winter months, but that the majority of the exposure will be received from indoor and outdoor exposures during the warmer time of the year. As a result of the detailed analysis, each age group experiences a slightly different exposure, and the calculated annual average daily contact rates range between approximately 10 to 1200 mg of soil per day. The step-wise process followed in the calculation of the exposure rates is summarized below and detailed in Tables A-5 through A-9.

STEP 1: For exposures which occur indoors, the amount of soil which comes into contact with the receptor's skin is calculated in Table A-5. This contact rate is for those days when exposure is thought to occur. The indoor exposure is quantified for ages 0 - 6. During the colder months only the hands are assumed to be regularly exposed to household dust, and infants are assumed not to be exposed. During the warmer months children are assumed to have a greater surface area exposed. The amount of soil in contact with the skin is dependent upon the surface area of the exposed body parts, the adherence of the dust to the skin, and the fraction of the household dust derived from soil sources.

TABLE A-5

INDOORS ONLY - DERMAL CONTACT					
OCTOBER - APRIL					
Exposed AGE	Body Parts and % of Total Body Surface Area ¹	Total Body Surface Area ²	Adherence Factor ³	Fraction of Dust Derived From Soil ⁴	Soil In Contact With Skin On Days Exposed INDOORS ONLY ⁵
years		cm ²	mg/cm ²		mg soil/day
< 1	none, -	4450 ⁶	0.056	0.8	-
1 < 2	hands, 5.68%	5130 ⁶	0.056	0.8	13.1
2 < 3	hands, 5.3%	5790	0.056	0.8	13.7
3 < 4	hands, 6.1%	6490	0.056	0.8	17.7
4 < 5	hands, 5.7%	7060	0.056	0.8	18.0
5 < 6	hands, 5.7%	7790	0.056	0.8	19.9
> 6	none, -	-	0.056	0.8	-
MAY - SEPTEMBER					
Exposed AGE	Body Parts and % of Total Body Surface Area	Total Body Surface Area ²	Adherence Factor ³	Fraction of Dust Derived From Soil ⁴	Soil In Contact With Skin On Days Exposed INDOORS ONLY ⁵
years		cm ²	mg/cm ²		mg soil/day
< 1	Hands, Arms, Legs, Feet, 46%	4450	0.056	0.8	91.7
1 < 2	Hands, Arms, Legs, Feet, 48%	5130	0.056	0.8	110.3
2 < 3	Hands, Arms, Legs, Feet, 47%	5790	0.056	0.8	121.9
3 < 4	Hands, Arms, Legs, Feet, 54%	6490	0.056	0.8	157.0
4 < 5	Hands, Arms, Legs, Feet, 55%	7060	0.056	0.8	174.0
5 < 6	Hands, Arms, Legs, Feet, 52% ⁷	7790	0.056	0.8	181.5
> 6	none, -	-	0.056	0.8	-
<p>1 - Percentage of total body surface area by body part taken from U.S. EPA, 1989b, (mean values, p.4-12).</p> <p>2 - 50th Percentile values for Total Body Surface Areas taken from U.S. EPA, 1989b (p. 4-31), except as noted below (6).</p> <p>3 - Hawley, 1985</p> <p>4 - Hawley, 1985</p> <p>5 - The soil in contact with the skin (on days exposed) during this time period for the age group specified. Example calculation, age <1: $0.46 * 4450 * 0.056 * 0.8 = 91.7 \text{ mg soil}$</p> <p>6 - The total body surface area for ages <1 and 1<2 have been estimated using the equation $SA = K * BW^{2/3}$ (U.S. EPA, 1989b, p. 4-20), where SA = Surface Area, K is a constant (estimated from data available for ages 2<3) and BW is the receptor's body weight (Table 8-8).</p> <p>7 - Data are unavailable for this age group. The Percentage of total body surface area used here is assumed to be equal to that for the 6 > 7 year old.</p>					

STEP 2: For the days when the receptor is exposed both indoors and outdoors, the amount soil in contact is calculated in Table A-6. This contact rate is for those days when exposure is thought to occur. Exposure to adults is quantified here as it is assumed that all ages have the opportunity for contact with the soil through play or gardening.

TABLE A-6

INDOORS & OUTDOORS - DERMAL CONTACT					
MAY - SEPTEMBER					
AGE	Exposed Body Parts and % of Total Body Surface Area ¹ years	Total Body Surface Area ² cm ²	Adherence Factor ³ mg/cm ²	Fraction Adhered Material Derived from Soil ⁴	Soil In Contact With Skin On Days Exposed Both Indoors & Outdoors ⁵ mg soil/day
< 1	none, -	4450 ⁶	0.51	0.8	0
1 < 2	Hands, Arms, Legs, Feet, 48%	5130 ⁶	0.51	0.8	1005
2 < 3	Hands, Arms, Legs, Feet, 47%	5790	0.51	0.8	1110
3 < 4	Hands, Arms, Legs, Feet, 54%	6490	0.51	0.8	1430
4 < 5	Hands, Arms, Legs, Feet, 55%	7060	0.51	0.8	1584
5 < 6		7790	0.51	0.8	1653
6 < 7	Hands, Arms, Legs, Feet, 52% [?]	8430	0.51	0.8	1789
7 < 8	Hands, Arms, Legs, Feet, 52%	9170	0.51	0.8	2020
8 < 9	Hands, Arms, Legs, Feet, 54% [?]	10000	0.51	0.8	2203
9 < 10	Hands, Arms, Legs, Feet, 54% [?]	10600	0.51	0.8	2335
10 < 11	Hands, Arms, Legs, Feet, 54%	11700	0.51	0.8	2721
11 < 12	Hands, Arms, Legs, Feet, 57% [?]	13000	0.51	0.8	3023
12 < 13	Hands, Arms, Legs, Feet, 57% [?]	14000	0.51	0.8	3256
13 < 14	Hands, Arms, Legs, Feet, 57%	14800	0.51	0.8	3442
14 < 15		15500	0.51	0.8	3731
15 < 16	Hands, Arms, Legs, Feet, 57%	15700	0.51	0.8	3779
16 < 17	Hands, Arms, Legs, Feet, 59% [?]	16000	0.51	0.8	3852
17 < 18	Hands, Arms, Legs, Feet, 59% [?]	16300	0.51	0.8	4057
18 < 30	Hands, Arms, Legs, Feet, 59%	16900	0.51	0.8	2069
	Hands, Arms, Legs, Feet, 61%				
	Hands, Forearms, Lower legs, Feet, 30%				

- 1 - Mean values for Percentage of total body surface area by body part taken from U.S. EPA, 1989b (pp. 4-11 & 4-12), except as noted below (7).
- 2 - 50th Percentile Total Body Surface Areas taken from U.S. EPA, 1989b (pp. 4-29 & 4-31), except as noted below (6).
- 3 - Hawley, 1985
- 4 - Hawley, 1985
- 5 - The soil in contact with the skin (on days exposed) during this time period for the age group specified. Example calculation, age 1 < 2: $0.48 * 5130 * 0.51 * 0.8 = 1005 \text{ mg soil/day}$
- 6 - The total body surface area for ages <1 and 1<2 have been estimated using the equation $SA = K * BW^{2/3}$ (U.S. EPA, 1989b, p. 4-20), where SA = Surface Area, K is a constant (estimated from data available for ages 2<3) and BW is the receptor's body weight (Table A-7).
- ? - Data are unavailable for this age group. The Percentage of total body surface area used here is taken from the next oldest age group for which data is available (i.e., the % for the 6<7 yr old is used for the 5<6 age group).

STEP 3: The indoor and outdoor soil contact rates (the results of Tables A-5 and A-6, respectively) are then combined with exposure frequency assumptions to yield an average daily soil contact rate for the year. These rates are presented in Table A-7, and range between 10 to 1200 mg soil per day, depending upon the age of the receptor.

TABLE A-7

CALCULATION OF AGE-SPECIFIC SOIL DERMAL CONTACT RATES							
AGE years	SOIL DERMAL CONTACT RATES ** On days exposed **			FREQUENCY OF EXPOSURE			ANNUAL AVERAGE 365 d
	Indoor Only Oct -> April ¹	Indoor Only May -> Sept. ²	Indoor & Outdoor May -> Sept. ³	Indoor Only Oct -> April ⁴ of 212 days	Indoor Only May -> Sept. ⁵ of 153 days	Indoor & Outdoor May -> Sept. ⁶ of 153 days	DAILY SOIL DERMAL CONTACT RATE ⁷ mg soil/d
< 1	0	91.7	0	0	44	0	11.1
1 < 2	13.1	110.3	1005	212	44	109	321
2 < 3	13.7	121.9	1110	212	44	109	354
3 < 4	17.7	157.0	1430	212	44	109	456
4 < 5	18.0	174.0	1584	212	44	109	504
5 < 6	19.9	181.5	1653	212	44	109	527
6 < 7	0	0	1789	0	0	109	534
7 < 8	0	0	2020	0	0	109	603
8 < 9	0	0	2203	0	0	109	658
9 < 10	0	0	2335	0	0	109	697
10 < 11	0	0	2721	0	0	109	813
11 < 12	0	0	3023	0	0	109	903
12 < 13	0	0	3256	0	0	109	972
13 < 14	0	0	3442	0	0	109	1028
14 < 15	0	0	3731	0	0	109	1114
15 < 16	0	0	3779	0	0	109	1129
16 < 17	0	0	3852	0	0	109	1150
17 < 18	0	0	4057	0	0	109	1212
18 < 30	0	0	2069	0	0	109	618

- 1 - Indoor Only Contact Rates for Oct. through April taken from Table A-5.
- 2 - Indoor Only Contact Rates for May through Sept. taken from Table A-5.
- 3 - Contact Rates on days when both indoor and outdoor exposure is thought to occur taken from Table A-6.
- 4 - 212 days is approximately 7 days/week from October through April.
- 5 - 44 days is approximately 2 days/week from May through September.
- 6 - 109 days is approximately 5 days/week from May through September.
- 7 - The average daily exposure to soil in dermal contact with the skin for this age group, adjusted for the frequency of exposure.

Example calculation, age 2<3 years:

$$((13.7 * 212) + (121.9 * 44) + (1110 * 109))/365 = 354 \text{ mg soil/day}$$

STEP 4: The annual average contact rates derived in Table A-7 are then normalized to the body weight of each age group and weighted by the number of years in that age group. This calculation is presented in Table A-8.

TABLE A-8

CALCULATION OF TIME-WEIGHTED AVERAGE DAILY SOIL DERMAL CONTACT EXPOSURES NORMALIZED TO BODYWEIGHT				
AGE	MEDIAN BODY WEIGHT¹	SOIL DERMAL CONTACT RATE²	WEIGHTING FACTOR³	DAILY SOIL DERMAL CONTACT RATE FOR THE TIME PERIOD⁴
years	kilograms	years mg soil/day	(mg * yrs)/(kg * d)	
< 1	8.5	11.1	1	1.3
1 < 2	10.5	321	1	30.6
2 < 3	12.6	354	1	28.1
3 < 4	14.6	456	1	31.2
4 < 5	16.4	504	1	30.7
5 < 6	18.8	527	1	28.0
6 < 7	21.0	534	1	25.4
7 < 8	23.5	603	1	25.7
8 < 9	27.3	658	1	24.1
9 < 10	29.6	697	1	23.5
10 < 11	34.3	813	1	23.7
11 < 12	40.0	903	1	22.6
12 < 13	45.2	972	1	21.5
13 < 14	48.6	1028	1	21.2
14 < 15	52.8	1114	1	21.1
15 < 16	53.9	1129	1	20.9
16 < 17	55.3	1150	1	20.8
17 < 18	58.3	1212	1	20.8
18 < 25	57.1	618	7	75.8
25 < 30	59.9	618	5	51.6

- 1 - 50th percentile body weights taken from U.S. EPA, 1989b, pp. 5-43 & 5-45.
- 2 - Soil Dermal Contact calculated in Table A-7.
- 3 - Weighting Factor is equal to the number of years represented by each age group.
- 4 - The Soil Dermal Contact Rate Normalized to Body Weight for the specified time period. Example Calculation, age 1 < 2:

$$[(321 \text{ mg soil/d}) * 1 \text{ yr}] / 10.5 \text{ kg} = 30.6 \text{ (mg * yr)/(kg * d)}$$

STEP 5: Finally, these age-specific values are combined to yield the time-weighted, normalized exposure rates used to calculate the risk-based concentrations. These values are developed in Table A-9 and the results summarized in Table 5-1.

TABLE A-9

For the evaluation of non-cancer risk-based concentrations, the averaging period is equal to the exposure period. For cancer risk-based concentrations, the averaging period is a lifetime (75 years), independent of the length of the exposure period (MA DEQE, 1989a).			
CALCULATION OF THE NORMALIZED DAILY SOIL DERMAL CONTACT RATES USED FOR S - 1 STANDARD SETTING			
NONCANCER RISK		CANCER RISK	
AGE	DAILY SOIL DERMAL CONTACT RATE FOR THE TIME PERIOD	AGE	DAILY SOIL DERMAL CONTACT RATE FOR THE TIME PERIOD
years	(mg * yrs)/(kg * d)	years	(mg * yrs)/(kg * d)
1 < 2	30.6	< 1	1.3
2 < 3	28.1	1 < 2	30.6
3 < 4	31.2	2 < 3	28.1
4 < 5	30.7	3 < 4	31.2
5 < 6	28.0	4 < 5	30.7
6 < 7	25.4	5 < 6	28.0
7 < 8	25.7	6 < 7	25.4
	-----	7 < 8	25.7
# Years = 7	SUM: 199.7	8 < 9	24.1
		9 < 10	23.5
		10 < 11	23.7
		11 < 12	22.6
		12 < 13	21.5
		13 < 14	21.2
		14 < 15	21.1
		15 < 16	20.9
		16 < 17	20.8
		17 < 18	20.8
		18 < 25	75.8
		25 < 30	51.6
		Exposure Period = 30 yr	SUM: 548.6
		AVERAGING PERIOD	
		75 Years	
		Normalized Lifetime Average Daily Soil Dermal Contact Rate:	
		199.7/7 = 28.5 mg soil/(kg*day)	548.6/75 = 7.3 mg soil/(kg * day)

APPENDIX B

DERIVATION OF SOIL S-2

NORMALIZED AVERAGE DAILY SOIL INGESTION RATE
(NADSIR)

NORMALIZED AVERAGE DAILY SOIL/SKIN CONTACT RATE
(NADSCR)

NORMALIZED LIFETIME AVERAGE DAILY SOIL INGESTION RATE
(NLADSIR)

NORMALIZED LIFETIME AVERAGE DAILY SOIL/SKIN CONTACT RATE
(NLADSCR)

APPENDIX B

DERIVATION OF SOIL S-2 EXPOSURE RATES

1. SOIL INGESTION RATES:

This section describes the development of the soil ingestion rates used to calculate the S-2 soil standards. These values are age specific and normalized to body weight. The step-wise process followed in the calculation of the exposure rates is summarized below.

STEP 1: An annual average daily soil intake was developed for each age group, as shown in Table B-1. This value is weighted to reflect the relative time spent outdoors where greater exposure to soil would be expected. The resulting soil ingestion rates are then used in Step 2.

TABLE B-1

SOIL S-2 CALCULATION OF AGE-SPECIFIC SOIL INGESTION RATES				
AGE	RATE OF EXPOSURE	FREQUENCY OF EXPOSURE		ANNUAL AVERAGE 365 days
	Outdoor Exposure Rate ¹	Winter ² Nov. -> March of 151 days	Outdoors ³ April -> Oct. of 214 days	DAILY SOIL INGESTION RATE ⁴
years	mg soil/d	days	days	mg soil/d
18 < 25	50	0	129	17.7
25 < 35	50	0	129	17.7
35 < 45	50	0	129	17.7

1 - Soil Ingestion Rate on days when outdoor exposures may occur taken from LaGoy (1987)

2 - No outdoor exposure to soil is assumed to occur during this period.

3 - 129 days approximates outdoor exposures 5 days/week, less approximately 24 days when exposure doesn't occur due to weather, vacations, etc...

4 - The average daily soil ingestion rate for this age group, adjusted for the frequency of exposure. Example, age 18 < 25 years:

$$(50 \text{ mg/d} * 129 \text{ d})/365 \text{ days} = 17.7 \text{ mg soil/day}$$

STEP 2: The soil ingestion rates from Step 1 are normalized to the body weight of each age group and weighted for the number of years in that age group. This calculation is presented in Table B-2.

TABLE B-2

**CALCULATION OF TIME-WEIGHTED AVERAGE DAILY SOIL
INGESTION EXPOSURES
NORMALIZED TO BODYWEIGHT**

AGE	MEDIAN BODY WEIGHT ¹	SOIL INGESTION RATE ²	WEIGHTING FACTOR ³	DAILY SOIL INGESTION RATE FOR THE TIME PERIOD
years	kilograms	years mg soil/day	(mg * yrs)/(kg * d)	
18 < 25	57.1	17.7	7	2.17
25 < 35	59.9	17.7	10	2.95
35 < 45	62.4	17.7	10	2.84

1 -	50 th percentile body weights taken from U.S. EPA, 1989b, pp. 5-43 & 5-45.
2 -	Soil Ingestion Rate calculated in Table B-1.
3 -	Weighting Factor is equal to the number of years represented by each age group.
4 -	The Soil Ingestion Rate Normalized to Body Weight for the specified time period.
	Example Calculation, age 18 < 25:
	$[(17.7 \text{ mg soil/d}) * 7 \text{ yr}] / 57.1 \text{ kg} = 2.17 \text{ (mg * yr)/(kg * d)}$

STEP 3: Finally, these age-specific values are combined to yield the time-weighted, normalized values used to calculate the risk-based concentration for Category S-2 soil. These values are developed in Table B-3, and the results summarized in Table 5-3.

TABLE B-3

CALCULATION OF THE NORMALIZED DAILY SOIL INTAKE RATES USED TO CALCULATE S-2 SOIL STANDARDS			
NONCANCER EFFECTS		CARCINOGENIC EFFECTS	
AGE	DAILY SOIL INGESTION RATE FOR THE TIME PERIOD	AGE	DAILY SOIL INGESTION RATE FOR THE TIME PERIOD
years	(mg * yrs)/(kg * d)	years	(mg * yrs)/(kg * d)
18 < 25	2.17	18 < 25	2.17
25 < 35	2.95	25 < 35	2.95
35 < 45	2.84	35 < 45	2.84
	-----		-----
# Years = 27	SUM: 7.96	Exposure Period = 27 yr	SUM: 7.96
Normalized Average Daily Soil Intake Rate:		Normalized Lifetime Average Daily Soil Intake Rate:	
7.96/27 = 0.29 mg soil/(kg*day)		7.96/75 = 0.11 mg soil/(kg * day)	
For the calculation of non-cancer risk-based concentrations, the averaging period is equal to the exposure period. For cancer risk-based concentrations, the averaging period is a lifetime (75 years), independent of the length of the exposure period (MA DEQE, 1989a).			

2. DERMAL CONTACT RATES

This section will describe the development of the rates of contact between the soil and the receptor's skin. Absorption through the skin is potentially an important route of exposure which depends, in part, on the exposed skin surface area. Since surface area varies by age, the soil/dermal contact rate would be expected to vary by age as well. The values are age-specific and are normalized to body weight. As a result of the detailed analysis, each age group experiences a slightly different exposure. The step-wise process followed in the calculation of the exposure rates is summarized below and detailed in Tables B-4 through B-7.

STEP 1: For outdoor exposures, the amount of soil which comes into contact with the receptor's skin is calculated in Table B-4. This contact rate is for those days when exposure is thought to occur. The amount of soil in contact with the skin is dependent upon the surface area of the exposed body parts and the adherence of the soil to the skin.

TABLE B-4

OUTDOORS - DERMAL CONTACT

APRIL - OCTOBER

AGE years	Exposed Body Parts and % of Total Body Surface Area ¹	Total Body Surface Area ² cm ²	Adherence Factor ³ mg/cm ²	Soil In Contact With Skin On Days Exposed Outdoors ⁴ mg soil/day
18 < 25	Hands, Forearms, Lower legs, Feet, 30%	16900	0.51	2586
25 < 35	Hands, Forearms, Lower legs, Feet, 30%	16900	0.51	2586
35 < 45	Hands, Forearms, Lower legs, Feet, 30%	16900	0.51	2586

1 - Mean values for Percentage of total body surface area by body part taken from U.S. EPA, 1989b (pp. 4-11).

2 - 50th Percentile Total Body Surface Areas taken from U.S. EPA, 1989b (pp. 4-29).

3 - Hawley, 1985

4 - The soil in contact with the skin (on days exposed) during this time period for the age group specified. Example calculation,

age 25 < 35:

$$0.30 * 16900 * 0.51 = 2586 \text{ mg soil/day}$$

STEP 2: The outdoor soil contact rates (Table B-4) are then combined with exposure frequency assumptions to yield an average daily soil contact rate for the year. These rates are presented in Table B-5.

TABLE B-5

CALCULATION OF AGE-SPECIFIC SOIL DERMAL CONTACT RATES					
AGE	SOIL DERMAL CONTACT RATES ** On days exposed **		FREQUENCY OF EXPOSURE		ANNUAL AVERAGE 365 days
	Winter Nov -> March ¹	Outdoor April -> Oct. ³	Nov -> March ⁴ of 151 days	Outdoor April -> Oct. ⁶ of 214 days	DAILY SOIL DERMAL CONTACT RATE ⁷
years	mg soil/day	mg soil/day	days	days	mg soil/d
18 < 25	0	2586	0	129	914
25 < 35	0	2586	0	129	914
35 < 45	0	2586	0	129	914

- 1 - No exposure to soil is thought to occur during this time.
- 2 - Contact Rates on days when outdoor exposure is thought to occur taken from Table B-4.
- 3 - 129 days approximates outdoor exposures 5 days/week, less approximately 24 days when exposure doesn't occur due to weather, vacations, etc...
- 4 - The average daily exposure to soil in dermal contact with the skin for this age group, adjusted for the frequency of exposure. Example calculation, age 25 < 35 years:
(2586 * 129)/365 = 914 mg soil/day

STEP 3: The annual average contact rates derived in Table B-5 are then normalized to the body weight of each age group and weighted by the number of years in that age group. This calculation is presented in Table B-6.

TABLE B-6

CALCULATION OF TIME-WEIGHTED AVERAGE DAILY SOIL DERMAL CONTACT EXPOSURES NORMALIZED TO BODYWEIGHT				
AGE	MEDIAN SOIL DERMAL BODY WEIGHT¹	CONTACT RATE²	WEIGHTING FACTOR³	DAILY SOIL DERMAL CONTACT RATE FOR THE TIME PERIOD⁴
years	kilograms	mg soil/day	years	(mg * yrs)/(kg * d)
18 < 25	57.1	914	7	112.0
25 < 35	59.9	914	10	152.6
35 < 45	62.4	914	10	146.5

1 - 50th percentile body weights taken from U.S. EPA, 1989b, pp. 5-43.
 2 - Soil Dermal Contact calculated in Table B-5.
 3 - Weighting Factor is equal to the number of years represented by each age group.
 4 - The Soil Dermal Contact Rate Normalized to Body Weight for the specified time period. Example Calculation, age 35 < 45:

$$[(914 \text{ mg soil/d}) * 10 \text{ yr}] / 62.4 \text{ kg} = 146.5 \text{ (mg * yr)/(kg * d)}$$

STEP 4: Finally, these age-specific values are combined to yield the time-weighted, normalized exposure rates used to calculate the risk-based concentrations. These values are developed in Table B-7 and the results summarized in Table 5-1.

TABLE B-7

CALCULATION OF THE NORMALIZED DAILY SOIL DERMAL CONTACT RATES USED TO CALCULATE S-2 STANDARDS			
NONCANCER EFFECTS		CARCINOGENIC EFFECTS	
AGE <small>years</small>	DAILY SOIL DERMAL CONTACT RATE FOR THE TIME PERIOD <small>(mg * yrs)/(kg * d)</small>	AGE <small>years</small>	DAILY SOIL DERMAL CONTACT RATE FOR THE TIME PERIOD <small>(mg * yrs)/(kg * d)</small>
18 < 25	112.0	18 < 25	112.0
25 < 35	152.6	25 < 35	152.6
35 < 45	146.5	35 < 45	146.5
# Years = 27	SUM: 411.1	Exposure Period = 27 yr	SUM: 411.1
Normalized Average Daily Soil Dermal Contact Rate: 411.1/27 = 15.2 mg soil/(kg*day)		AVERAGING PERIOD 75 Years	
For the non-cancer risk concentration, the averaging period is equal to the exposure period. For cancer risk, the averaging period is a lifetime (75 years), independent of the length of the exposure period (MA DEQE, 1989a).		Normalized Lifetime Average Daily Soil Dermal Contact Rate: 411.1/75 = 5.48 mg soil/(kg * day)	

APPENDIX C

DERIVATION OF SOIL S-3

NORMALIZED AVERAGE DAILY SOIL INGESTION RATE
(NADSIR)

NORMALIZED AVERAGE DAILY SOIL/SKIN CONTACT RATE
(NADSCR)

NORMALIZED LIFETIME AVERAGE DAILY SOIL INGESTION RATE
(NLADSIR)

NORMALIZED LIFETIME AVERAGE DAILY SOIL/SKIN CONTACT RATE
(NLADSCR)

APPENDIX C

DERIVATION OF SOIL S-3 EXPOSURE RATES

1. SOIL INGESTION RATES:

This section describes the development of the soil ingestion rates used to calculate the S-3 soil standards. These values are age specific and normalized to body weight. The step-wise process followed in the calculation of the exposure rates is summarized below.

STEP 1: An annual average daily soil intake was developed for each age group, as shown in Table C-1. This value is weighted to reflect the relative time spent outdoors where greater exposure to soil would be expected. The resulting soil ingestion rates are then used in Step 2.

TABLE C-1

SOIL S-3 CALCULATION OF AGE-SPECIFIC SOIL INGESTION RATES					
AGE years	RATE OF EXPOSURE		FREQUENCY OF EXPOSURE		DAILY SOIL INGESTION RATE ⁵ mg soil/d
	Outdoor Exposure Rate ¹ mg soil/d	June, July, August ² of 92 days days	April, May, Sept, Oct. ³ of 122 days days	Averaging Period ⁴ days	
18 < 25	50	56	73	365	17.7
22	50	66	0	92	35.9

1 - Soil Ingestion Rate on days when outdoor exposures may occur taken from LaGoy (1987)
 2 - 56 days approximates 5 days/week less 10 days when exposure doesn't occur due to weather, vacations, etc... 66 days assumes 5 days/week.
 3 - 73 days approximates outdoor exposures 5 days/week, less approximately 15 days when exposure doesn't occur due to weather, vacations, etc...
 4 - The seven year exposure is expressed as an annual (365 day) average, but the 3 month exposure is averaged over the exposure period.
 5 - The average daily soil ingestion rate for this age group, adjusted for the frequency of exposure.
 Example, age 18 < 25 years:

$$((50 \text{ mg/d} * 56 \text{ d}) + (50 \text{ mg/d} * 73 \text{ d}))/365 \text{ days} = 17.7 \text{ mg soil/day}$$

STEP 2: The soil ingestion rates from Step 1 are normalized to the body weight of each age group and weighted for the number of years in that age group. This calculation is presented in Table C-2.

TABLE C-2
CALCULATION OF TIME-WEIGHTED AVERAGE DAILY SOIL
INGESTION EXPOSURES
NORMALIZED TO BODYWEIGHT

AGE years	MEDIAN BODY WEIGHT ¹ kilograms	SOIL INGESTION RATE ² mg soil/day	WEIGHTIN G FACTOR ³	DAILY SOIL INGESTION RATE FOR THE TIME PERIOD ⁴
18 < 25	57.1	17.7	7	2.17 (mg*yr)/(kg*d)
22	57.1	35.9	92	57.8 (mg*d)/(kg*d)

- 1 - 50th percentile body weights taken from U.S. EPA, 1989b, pp. 5-43.
 - 2 - Soil Ingestion Rate calculated in Table C-1.
 - 3 - Weighting Factor is equal to the number of years or days represented by each age group.
 - 4 - The Soil Ingestion Rate Normalized to Body Weight for the specified time period.
- Example Calculation, age 18 < 25:

$$[(17.7 \text{ mg soil/d}) * 7 \text{ yr}] / 57.1 \text{ kg} = 2.17 \text{ (mg * yr) / (kg * d)}$$

STEP 3: Finally, these age-specific values are combined to yield the time-weighted, normalized values used to calculate the risk-based concentration for Category S-3 soil. These values are developed in Table C-3, and the results summarized in Table 5-1.

TABLE C-3

CALCULATION OF THE NORMALIZED DAILY SOIL INTAKE RATES USED TO CALCULATE S-3 SOIL STANDARDS			
NONCANCER EFFECTS		CARCINOGENIC EFFECTS	
AGE	DAILY SOIL INGESTION RATE FOR THE TIME PERIOD	AGE	DAILY SOIL INGESTION RATE FOR THE TIME PERIOD
years	(mg * yrs)/(kg * d)	years	(mg * yrs)/(kg * d)
22	57.8	18 < 25	2.17
# days = 92		Exposure Period = 7 yr	
SUM: 57.8		SUM: 2.17	
Normalized Average Daily Soil Intake Rate:		AVERAGING PERIOD	
$57.8/92 = 0.63 \text{ mg soil}/(\text{kg}*\text{day})$		75 Years	
Normalized Lifetime Average Daily Soil Intake Rate:		$2.17/75 = 0.029 \text{ mg soil}/(\text{kg} * \text{day})$	

For the calculation of non-cancer risk-based concentrations, the averaging period is equal to the exposure period. For cancer risk-based concentrations, the averaging period is a lifetime (75 years), independent of the length of the exposure

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2. DERMAL CONTACT RATES

This section describes the development of the rates of contact between the soil and the receptor's skin. Absorption through the skin is potentially an important route of exposure which depends, in part, on the exposed skin surface area. Since surface area varies by age, the soil/dermal contact rate would be expected to vary by age as well. The values are age-specific and normalized to body weight. As a result of the detailed analysis, each age group experiences a slightly different exposure. The step-wise process followed in the calculation of the exposure rates is summarized below and detailed in Tables C-4 through C-7.

STEP 1: For outdoor exposures, the amount of soil which comes into contact with the receptor's skin is calculated in Table C-4. This contact rate is for those days when exposure is thought to occur. The amount of soil in contact with the skin is dependent upon the surface area of the exposed body parts and the adherence of the soil to the skin.

TABLE C-4

OUTDOORS - DERMAL CONTACT

AGE years	Exposed Body Parts and % of Total Body Surface Area ¹	Total Body Surface Area ² cm ²	Adherence Factor ³ mg/cm ²	<u>APRIL - OCTOBER</u>
				Soil In Contact With Skin On Days Exposed Outdoors ⁵ mg soil/day
18 < 25	Hands, Forearms, Lower legs, Feet, 30%	16900	0.51	2586
22	Hands, Forearms, Lower legs, Feet, 30%	16900	0.51	2586

1 - Mean values for Percentage of total body surface area by body part taken from U.S. EPA, 1989b (pp. 4-11).

2 - 50th Percentile Total Body Surface Areas taken from U.S. EPA, 1989b (pp. 4-29).

3 - Hawley, 1985

4 - The soil in contact with the skin (on days exposed) during this time period for the age group specified.

Example calculation, age 18 < 25:

$$0.30 * 16900 * 0.51 = 2586 \text{ mg soil/day}$$

STEP 2: The outdoor soil contact rates (Table C-4) are then combined with exposure frequency assumptions to yield an average daily soil contact rate for the year. These rates are presented in Table C-5.

TABLE C-5
CALCULATION OF AGE-SPECIFIC SOIL DERMAL CONTACT RATES

AGE	SOIL DERMAL CONTACT RATES ** On days exposed **		FREQUENCY OF EXPOSURE		Averaging Period ⁴	DAILY SOIL DERMAL CONTACT RATE ⁵ mg soil/d
	June, July, August ¹	April, May, Sept, Oct. ¹	June, July August ² of 92 days	April, May, Sept, Oct. ³ of 122 days		
years	mg soil/day	mg soil/day	days	days		
18 < 25	2586	2586	56	73	365 days	914
22	2586	2586	66	0	92 days	1855

- 1 - Contact Rates on days when outdoor exposure is thought to occur taken from Table C-4.
- 2 - 56 days approximates 5 days/week less 10 days when exposure doesn't occur due to weather, vacations, etc... 66 days assumes 5 days/week.
- 3 - 73 days approximates outdoor exposures 5 days/week, less approximately 15 days when exposure doesn't occur due to weather, vacations, etc...
- 4 - The seven year exposure is expressed as an annual (365 day) average, but the 3 month exposure is averaged over the exposure period.
- 5 - The average daily exposure to soil in dermal contact with the skin for this age group, adjusted for the frequency of exposure. Example calculation, age 18 < 25 years:

$$((2586 * 56) + (2586 * 73))/365 = 914 \text{ mg soil/day}$$

STEP 3: The annual average contact rates derived in Table C-5 are then normalized to the body weight of each age group and weighted by the number of years in that age group. This calculation is presented in Table C-6.

TABLE C-6
CALCULATION OF TIME-WEIGHTED AVERAGE DAILY SOIL DERMAL CONTACT EXPOSURES NORMALIZED TO BODYWEIGHT

AGE	MEDIAN BODY WEIGHT ¹	SOIL DERMAL CONTACT RATE ²	WEIGHTING FACTOR ³	DAILY SOIL DERMAL CONTACT RATE FOR THE TIME PERIOD ⁴
Years	kilograms	mg soil/day	years	
18 < 25	57.1	914	7	112.0 (mg * yrs)/(kg * d)
22	57.1	1855	92	2988.8 (mg * d)/(kg * d)

- 1 - 50th percentile body weights taken from U.S. EPA, 1989b, pp. 5-43.
- 2 - Soil Dermal Contact calculated in Table C-5.
- 3 - Weighting Factor is equal to the time (years & days, respectively) represented by each age group.
- 4 - The Soil Dermal Contact Rate Normalized to Body Weight for the specified time period.
 Example Calculation, age 18 < 25: $[(914 \text{ mg soil/d}) * 7 \text{ yr}]/57.1 \text{ kg} = 112.0 \text{ (mg * yr)/(kg * d)}$

STEP 4: Finally, these age-specific values are combined to yield the time-weighted, normalized exposure rates used to calculate the risk-based concentrations. These values are developed in Table C-7 and the results summarized in Table 5-1.

TABLE C-7

CALCULATION OF THE NORMALIZED DAILY SOIL DERMAL CONTACT RATES USED TO CALCULATE S-3 STANDARDS			
NONCANCER EFFECTS		CARCINOGENIC EFFECTS	
AGE	DAILY SOIL DERMAL CONTACT RATE FOR THE TIME PERIOD	AGE	DAILY SOIL DERMAL CONTACT RATE FOR THE TIME PERIOD
years	(mg * yrs)/(kg * d)	years	(mg * yrs)/(kg * d)
22	2988.8	18 < 25	112.0
# days = 92	SUM: 2988.8	Exposure Period = 7 yr	SUM: 112.0
Normalized Average Daily Soil Dermal Contact Rate:		AVERAGING PERIOD	
2988.8/92 = 32.5 mg soil/(kg*day)		75 Years	
<p>For the evaluation of non-cancer risk, the averaging period is equal to the exposure period. For cancer risk, the averaging period is a lifetime (75 years), independent of the length of the exposure period (MA DEQE, 1989a).</p>		Normalized Lifetime Average Daily Soil Dermal Contact Rate:	
		112.0/75 = 1.5 mg soil/(kg * day)	

APPENDIX D

**SOIL LEVELS WHICH TRIGGER
AN IMMINENT HAZARD EVALUATION**

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SOIL LEVELS WHICH TRIGGER AN IMMINENT HAZARD EVALUATION

NOTE: These levels are set generically to be protective under most exposure conditions. As such, the concentrations which follow are used to "screen in" conditions which may require further assessment or remedial action in the short-term. These trigger levels cannot be used to definitively "screen out" a disposal site, as it is possible (under more extreme exposure conditions) that concentrations below these levels could pose an imminent hazard. A site-specific assessment may conclude that the conditions at a disposal site pose an Imminent Hazard at concentrations which are higher or lower than those presented in the regulations.

310 CMR 40.0321(2)(b)

Hazardous Material	CAS Number	Concentration (µg/g dry wt)
Arsenic (total)	7440382	40
Cadmium (total)	7440439	60
Chromium (VI)	18540299	10,000
Cyanide (available)	57125	100
Mercury (total)	7439976	300
Methyl Mercury	22967926	10
PCB (total)	1336363	10

APPLICABILITY:

- Oil and/or hazardous material within a depth of 6 inches below the ground surface, and
- Within 500 feet of a residential dwelling, school, playground or public park, unless human access is controlled or prevented by means of bituminous pavement, concrete, or other physical barrier.

CONSEQUENCE:

- **Report to the Department** as soon as possible but not more than two hours after obtaining knowledge that a release meets these criteria.
- **Immediate Response Action (IRA) is required.** Immediate Response Actions are assessment and/or remedial actions undertaken in an expeditious manner to address sudden releases, Imminent Hazards and other time-critical release or site conditions. IRAs must taken whenever and wherever timely actions are required to assess, eliminate, abate or mitigate adverse or unacceptable release, threat of release and/or site conditions.
- Demonstration may be made to the Department by a preponderance of evidence that the conditions do not pose an Imminent Hazard.

EXPOSURES CONSIDERED

The Imminent Hazard Trigger Levels were identified through the evaluation of both carcinogenic and non-cancer risks: the lower of the two estimated concentrations is chosen to be the Trigger Level in order to be protective of both types of health effect. Due to the markedly different nature of these health effects, the calculations performed to evaluate the risks also differ. The following sections describe first the exposures assumed for the cancer risk calculations and then those assumed to evaluate the risk of non-cancer health impacts.

In general, the evaluation of soil ingestion and dermal contact exposures follows the methodology presented in various sections of this document, the Summary of Interim Procedures and Assumptions Used in Relating Soil Contaminant Levels and Risk to Human Health (MA DEP, 1993b), and in Section 8.0 of the Documentation for the Risk Assessment ShortForm - Residential Scenario (Policy #WSC/ORS-142-92, MA DEP, 1992). This approach uses age-specific exposure factors (such as body weight and skin surface area) to develop a time-weighted average exposure for each identified receptor.

Exposures Evaluated for the Cancer Risk Evaluation:

By definition, an Imminent Hazard is a hazard which would pose a significant risk if it were present for even a short period of time. The toxicological and risk assessment models used to estimate cancer risk, however, traditionally evaluate long-term exposure to environmental contaminants and are based upon a "*Lifetime Average Daily Dose*" of the substance. While the current state and federal approach to regulating carcinogens assumes that any exposure to a carcinogenic material is associated with some incremental cancer risk, estimating the incremental risk associated with a short exposure is problematic.

It is possible, however, to identify long-term risks which are so great that they indicate a need for remedial action in the short-term. This is the approach for developing the Imminent Hazard Trigger Levels: an excess lifetime cancer risk of one-in-ten-thousand (based on a 30-year exposure) is taken to be indicative of significant *short-term* cancer risk.

The Trigger Levels are applicable in areas where frequent exposure to surficial soil is likely. This exposure scenario is thus analogous to a residential exposure, and the exposure assumptions used in the development of the MCP Method 1 S-1 Soil Standards and the Risk Assessment ShortForm - Residential Scenario would be consistent with how the Trigger levels will be applied.

The residential exposure scenario assumes that a person (*receptor*) lives in a dwelling for thirty years. (The US EPA estimates that 95% of the population typically lives in the same location for less than thirty years). As children generally experience the highest exposures due to their play activities and low body weight, this analysis focuses on the ages of 0 to 30 years. Exposure to contaminated soil is assumed to vary by age and time of year. In the winter months (October through April), exposure is limited to soil which is part of household dust. In the warmer months, direct exposure to outdoor soil is also considered.

Equations:

$$[OHM]_{IHTL} = \frac{ELCR * C}{CSF * ((NLADSIR * RAF_3) + (NLADSCR * RAF_4))}$$

Where:

- [OHM]_{IHTL} = The calculated Imminent Hazard Trigger Level concentration in soil, for the oil or hazardous material. In units: mg/kg.
- ELCR = The target Excess Lifetime Cancer Risk: 1 x 10⁻⁴ (dimensionless).
- C = Units Concersion Factor: 1,000,000 mg/kg.
- NLADSIR = Time-weighted Normalized Lifetime Average Daily Soil Ingestion Rate (normalized to bodyweight). In units: mg_{soil}/kg/day.
- RAF = Relative Absorption Factor for soil ingestion or dermal contact for cancer risk calculations (a chemical-, medium-, route- and health-endpoint specific value). Dimensionless.
- NLADSCR = Time-weighted Normalized Lifetime Average Daily Soil Dermal Contact Rate (normalized to bodyweight). In units: mg_{soil}/kg/day
- CSF = The oral Carcinogenic Slope Factor for the oil or hazardous material. In units of 1/(mg/kg/day).

and

$$NLADSIR = \frac{\sum_{i=0}^{75 \text{ years}} \frac{(I1_i * F1) + (I2_i * (F2 + F3))}{365 \text{ days}}}{BW}$$

NLADSIR = 0.41 mg_{soil}/(kg_{BW} * day)

and

$$NLADSCR = \frac{\sum_{i=0}^{30 \text{ years}} (SA_i * FA * ((\%T1_i * AF1 * F1) + (\%T2_i * AF2 * F2) + (\%T3_i * AF3 * F3)))}{365 \text{ days} * BW}$$

NLADSCR =
75 years

NLADSCR = 7.3 mg_{soil}/(kg_{BW} * day)

Exposure Assumptions (Cancer Risk):

Receptor:	Resident	Aged 0 to 30 years
Exposure Duration:	30 years	
Frequency of Exposure:	F1: 212 days/year	Ages 1 to 6, indoor only: October -> April
	F2: 44 days/year	Ages 1 to 30, indoor only: May -> September
	F3: 109 days/year	Ages 1 to 30, indoor & outdoor: May -> September
Body Weight:	BW: 8.5 - 59.9 kg	Ages 0 to 30, age dependent
Soil Ingestion Rate:	I1: 8-31 mg/day	Ages 1 to 6, indoor only, age dependent
	I2: 100 mg/day	Ages 1 to 6, indoor & outdoor exposures: May -> September
	50 mg/day	Ages 6 to 30, indoor & outdoor exposures: May -> September
Exposed Surface Area:	SA: 4450-16900 cm ²	Ages 0 to 30 years, total body surface area, age dependent
	%T1: 5.3 - 5.7%	Ages 1 to 6 years, Percentage of total body surface area comprised by the hands only, indoor exposures: Oct. -> April.
	%T2: 46 - 55%	Ages 1 to 6 years, Percentage of total body surface area comprised by the hands, arms, legs and feet, indoor exposures: May -> September.
	%T3: 46 - 61%	Ages 1 to 18 years, Percentage of total body surface area comprised by the hands, arms, legs and feet, indoor & outdoor exposures: May -> September.
	30%	Ages 19 to 30 years, Percentage of total body surface area comprised of the hands, forearms, lower legs and feet: indoor & outdoor exposures: May -> September.
Soil Adherence Factor:	AF1: 0.056 mg/cm ²	Adherence of indoor dust to skin
	AF2: 0.51 mg/cm ²	Adherence of soil to skin
Fraction of Adhered Material Derived From Soil:	FA: 80 %	
Averaging Period:	AP: 75 years	A lifetime

Non-cancer Risk Evaluation:

Imminent Hazard Trigger levels also consider the potential for non-cancer health effects (such as central nervous system disorders) following exposure to oil or hazardous material. This evaluation is performed differently from the cancer risk-based calculation.

When evaluating non-cancer risk, the site-related exposure (or *dose*) experienced by the receptor is compared to a dose from the scientific literature at which no adverse health impacts would be expected. If the site-related dose is less than the identified literature value (or *Reference Dose*), then the site conditions do not pose an imminent hazard.

If the site-related dose is greater than the Reference Dose, then adverse health effects cannot be ruled out, **but the risk assessor cannot immediately conclude that the site conditions pose an imminent hazard.** Due to large variations in the quality of toxicological data available, the US EPA incorporates "*Uncertainty Factors (UFs)*" and "*Modifying Factors (MFs)*" into the Reference Dose to reflect the quality of the data and to insure that the Reference Dose falls below a No Observed Adverse Effects Level in sensitive humans. The less confidence there is in the original data, the larger the UF's and MF's. It is not uncommon that a Reference Dose incorporates combined factors as large as 10,000. On the other hand, the toxicological information available for some chemicals is complete, and the Uncertainty and Modifying Factors used to adjust the Reference Dose are quite small: sometimes less than a factor of ten. Thus the interpretation of a site-related exposure which exceeds a Reference Dose depends in part upon the magnitude of the UF's and MF's incorporated into the Reference Dose.

The ratio of the site-related dose over the Reference Dose is called the **Hazard Index** (or HI). In consideration of the magnitude of the Uncertainty Factors and Modifying Factors incorporated into the Reference Dose, the following criteria are used to calculate the Imminent Hazard Trigger Levels:

- If the magnitude of the UFs and MFs is **equal to or less than 10**, then the trigger levels are set at a Hazard Index = 1.
- If the magnitude of the UFs and MFs is **greater than 10**, then the trigger levels are set at a Hazard Index = 10.

The Reference Doses chosen to evaluate the site-related exposures should reflect the duration of the exposure itself. If the risk assessment looks at chronic exposures, then a chronic Reference Dose should be used. The evaluation of acute or subchronic exposures should employ acute or subchronic Reference Doses when they are available.

Exposures Evaluated for the Non-cancer Risk Evaluation:

The Trigger Levels are applicable in areas where frequent exposure to surficial soil is likely. This exposure scenario is thus analogous to a residential exposure, and the exposure assumptions used in the development of the MCP Method 1 S-1 Soil Standards and the Risk Assessment ShortForm - Residential Scenario would be consistent with how the Trigger levels will be applied. In a residential scenario, young children generally experience higher rates of exposure due to the nature of their activities and their low body weights. Thus this evaluation focuses on a child aged 5-6 years old exposed during the summer months (June through August) when frequent contact with soil is likely.

Equations:

$$I_{IHTL} = \frac{HI * RfD * C}{((ADSIR * RAF) + (ADSCR * RAF_2))}$$

Where:

- [OHM]_{IHTL} = The calculated Imminent Hazard Trigger Level concentration in soil, for the oil or hazardous material. In units: mg/kg.
- HI = The target Hazard Index level: 1 or 10, depending upon the magnitude of the UFs and MFs incorporated into the RfD (dimensionless).
- RfD = The oral Reference Dose or substitute toxicity value identified for the oil or hazardous material. In units of: mg/kg/day.
- C = Units Conversion Factor: 1,000,000 mg/kg.
- ADSIR = Average Daily Soil Ingestion Rate (normalized to bodyweight). In units: mg_{soil}/kg/day.
- RAF = Relative Absorption Factor for soil ingestion or dermal contact for cancer risk calculations (a chemical-, medium-, route- and health-endpoint specific value). Dimensionless.
- ADSCR = Average Daily Soil Dermal Contact Rate (normalized to bodyweight). In units: mg_{soil}/kg/day.

$$ADSIR = \frac{I * F * D}{BW * AP}$$

$$ADSIR = 5.3 \text{ mg}_{soil}/(\text{kgBW} * \text{day})$$

and

$$ADSCR = \frac{SA * \%T * AF * FA * F * D}{BW * AP}$$

$$ADSCR = 87.9 \text{ mg}_{soil}/(\text{kgBW} * \text{day})$$

Exposure Assumptions (Non-Cancer Risk):

<i>Receptor:</i>		Child Resident	Aged 5 to 6 years
<i>Exposure Duration:</i>	D:	3 months	
<i>Frequency of Exposure:</i>	F:	7 days/week, over	
		3 summer months:	92 days/3 months
<i>Body Weight:</i>	BW:	18.8 kg	Mean BW for child 5-6 years
<i>Soil Ingestion Rate:</i>	I:	100 mg/day	
<i>Exposed Surface Area:</i>	SA:	7790 cm ²	Age 5 to 6 years, total body surface area
	%T:	52%	Age 5 to 6 years, Percentage of total body surface area comprised by the hands, arms, legs and feet.
<i>Soil Adherence Factor:</i>	AF:	0.51 mg/cm ²	Adherence of soil to skin
			Fraction of Adhered Material
<i>Derived From Soil:</i>	FA:	80 %	
<i>Averaging Period:</i>	AP:	92 days	3 months, summer exposure

Arsenic

BASIS: Lowest Risk-Based Concentration:

Cancer: 30 year residential exposure, ages 0 to 30. Exposure parameters are age-specific and normalized to body weight (see earlier discussion for the calculation of soil exposure rates). Target risk level = one in ten thousand (10^{-4}). Carcinogenic Slope Factor = 1.75 per mg/kg/day, from USEPA *Integrated Risk Information System (IRIS)*.

$$[\text{OHM}]_{\text{soil}} = (\text{ELCR} \times C) / (\text{CSF} \times ((\text{RAF}_{\text{oral}} \times \text{NLADSIR}) + (\text{RAF}_{\text{dermal}} \times \text{NLADSCR})))$$

$$[\text{OHM}]_{\text{soil}} = (10^{-4} \times 10^6) / (1.75 \times ((1 \times 0.41) + (0.03 \times 7.3)))$$

$$[\text{OHM}]_{\text{soil, cancer}} = 90.8 \text{ mg/kg}$$

Noncancer: A 3 month (subchronic) residential exposure for a child age 5 < 6 years. Exposure assumed to occur daily (indoor & outdoor) over that period. Exposure parameters are age-specific (see earlier discussion for the calculation of soil exposure rates). Subchronic Reference Dose = 0.0003 mg/kg/day from USEPA *Health Effects Assessment Summary Tables (HEAST)*. Target Hazard Index value = 1 based upon the magnitude (3) of Uncertainty Factors and Modifying Factors used to derive the Subchronic Reference Dose.

$$[\text{OHM}]_{\text{soil}} = (\text{HI}_{\text{IH}} \times \text{RfD}_{\text{subchronic}} \times \text{C}) / ((\text{ADSIR} \times \text{RAF}_{\text{oral}}) + (\text{ADSCR} \times \text{RAF}_{\text{dermal}}))$$

$$[\text{OHM}]_{\text{soil}} = (1 \times 0.0003 \times 10^6) / ((5.3 \times 1) + (87.9 \times 0.03))$$

$$[\text{OHM}]_{\text{soil, noncancer}} = 37.8 \text{ mg/kg}$$

and

The Imminent Hazard Soil Trigger Level for Arsenic is based upon the potential non-cancer risks: 37.8 mg/kg < 90.8 mg/kg. Expressed in one significant figure, 37.8 rounds to 40 mg/kg (ppm).

Arsenic I.H. Trigger, Soil = **40 mg/kg**

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Cancer: Cadmium is not considered to be carcinogenic for exposures via the oral or dermal routes (USEPA Integrated Risk Information System).

Noncancer: A 3 month (subchronic) residential exposure for a child age 5 < 6 years. Exposure assumed to occur daily (indoor & outdoor) over that period. Exposure parameters are age-specific (see earlier discussion for the calculation of soil exposure rates). Subchronic Reference Dose = 0.001 mg/kg/day assumed to be equal to the chronic Reference Dose from USEPA Integrated Risk Information System (IRIS). Target Hazard Index value = 1 based upon the magnitude (10) of Uncertainty Factors and Modifying Factors used to derive the Subchronic Reference Dose.

$$[\text{OHM}]_{\text{soil}} = (\text{HI}_{\text{IH}} \times \text{RfD}_{\text{subchronic}} \times \text{C}) / ((\text{ADSIR} \times \text{RAF}_{\text{oral}}) + (\text{ADSCR} \times \text{RAF}_{\text{dermal}}))$$

$$[\text{OHM}]_{\text{soil}} = (1 \times 0.001 \times 10^6) / ((5.3 \times 1) + (87.9 \times 0.14))$$

Cyanide

BASIS: Lowest Risk-Based Concentration:
[OHM]_{soil, noncancer} = 56.8 mg/kg

The Imminent Hazard Soil Trigger Level for Cadmium is based upon the potential non-cancer risks: 56.8 mg/kg. No cancer risk-based concentration was calculated as cadmium is not considered to be carcinogenic via the oral or dermal routes of exposure. Expressed in one significant figure, 56.8 rounds to 60 mg/kg (ppm).

Cadmium I.H. Trigger, Soil = 60 mg/kg

Chromium (VI)

BASIS: Lowest Risk-Based Concentration:

Cancer: Chromium (VI) is not considered to be carcinogenic for exposures via the oral or dermal routes (USEPA *Integrated Risk Information System*).

Cyanide

BASIS: Lowest Risk-Based Concentration:

Noncancer: A 5 month (subchronic) residential exposure for a child age 5 < 6 years. Exposure assumed to occur daily (indoor & outdoor) over that period. Exposure parameters are age-specific (see earlier discussion for the calculation of soil exposure rates). Subchronic Reference Dose = 0.02 mg/kg/day assumed to be equal to the chronic Reference Dose from USEPA Integrated Risk Information System (IRIS). Target Hazard Index value = 10 based upon the magnitude (100) of Uncertainty Factors and Modifying Factors used to derive the Subchronic Reference Dose.

$$[\text{OHM}]_{\text{soil}} = (\text{HI}_{\text{IH}} \times \text{RfD}_{\text{subchronic}} \times \text{C}) / ((\text{ADSIR} \times \text{RAF}_{\text{oral}}) + (\text{ADSCR} \times \text{RAF}_{\text{dermal}}))$$

$$[\text{OHM}]_{\text{soil}} = (10 \times 0.02 \times 10^6) / ((5.3 \times 1) + (87.9 \times 0.1))$$

$$[\text{OHM}]_{\text{soil, noncancer}} = 14194 \text{ mg/kg}$$

The Imminent Hazard Soil Trigger Level for Chromium (VI) is based upon the potential non-cancer risks: 14194 mg/kg. No cancer risk-based concentration was calculated as hexavalent chromium is not considered to be carcinogenic via the oral or dermal routes of exposure. Expressed in one significant figure, 14194 rounds to 10,000 mg/kg (ppm).

Chromium (VI) I.H. Trigger, Soil = 10,000 mg/kg

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Cancer: Cyanide is not considered to be carcinogenic for exposures via the oral or dermal routes (USEPA Integrated Risk Information System).

Noncancer: A one-time (acute) residential exposure for a 2 year old child who weighs 10 kg. The acute exposure scenario assumes that a child may ingest one gram (10^3 mg) of soil as a one-time event, and that 100% of the physiologically available cyanide is absorbed. Dermal exposure was considered to be insignificant relative to the ingestion pathway for this acute exposure. The Allowable One-Time Absorbed Dose (AOTAD) = 0.01 mg/kg, derived from Gettler and Baine (1938), as described in Background Documentation for the Development of "Available" Cyanide Benchmark Concentrations (MA DEP, 1991). Target Hazard Index value = 1 based upon the severity of effect (lethality) which is the basis of the allowable dose.

$$[\text{OHM}]_{\text{soil}} = (\text{HI}_{\text{IH}} \times \text{AOTAD}_{\text{acute}} \times \text{BW} \times \text{C}) / (\text{I}_{\text{acute}} \times \text{RAF}_{\text{oral}})$$

$$[\text{OHM}]_{\text{soil}} = (1 \times 0.01 \text{ mg/kg} \times 10 \text{ kg} \times 10^6 \text{ mg/kg}) / (10^3 \text{ mg-soil} \times 1)$$

$$[\text{OHM}]_{\text{soil, noncancer}} = 100 \text{ mg/kg}$$

The Imminent Hazard Soil Trigger Level for Cyanide is based upon the potential non-cancer risks: 100 mg/kg. No cancer risk-based concentration was calculated as cyanide is not considered to be carcinogenic.

Cyanide I.H. Trigger, Soil = 100 mg/kg

Mercury

BASIS: Lowest Risk-Based Concentration:

Cancer: Mercury is not considered to be carcinogenic
(USEPA *Integrated Risk Information System*).

Noncancer: A 5 month (subchronic) residential exposure for a child age 5 < 6 years. Exposure assumed to occur daily (indoor & outdoor) over that period. Exposure parameters are age-specific (see earlier discussion for the calculation of soil exposure rates). Subchronic Reference Dose = 0.0003 mg/kg/day from USEPA Health Effects Assessment Summary Tables (HEAST). Target Hazard Index value = 10 based upon the magnitude (30) of Uncertainty Factors and Modifying Factors used to derive the Subchronic Reference Dose.

$$[\text{OHM}]_{\text{soil}} = (\text{HI}_{\text{IH}} \times \text{RfD}_{\text{subchronic}} \times \text{C}) / ((\text{ADSIR} \times \text{RAF}_{\text{oral}}) + (\text{ADSCR} \times \text{RAF}_{\text{dermal}}))$$

$$[\text{OHM}]_{\text{soil}} = (10 \times 0.0003 \times 10^6) / ((5.3 \times 1) + (87.9 \times 0.05))$$

$$[\text{OHM}]_{\text{soil, noncancer}} = 309 \text{ mg/kg}$$

The Imminent Hazard Soil Trigger Level for Mercury is based upon the potential non-cancer risks: 309 mg/kg. No cancer risk-based concentration was calculated as mercury is not considered to be carcinogenic. Expressed in one significant figure, 309 rounds to 300 mg/kg (ppm).

Mercury I.H. Trigger, Soil = 300 mg/kg

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Methyl Mercury

BASIS: Lowest Risk-Based Concentration:

Cancer: Methyl Mercury is not considered to be carcinogenic (USEPA *Integrated Risk Information System*).

Noncancer: A 5 month (subchronic) residential exposure for a child age 5 < 6 years. Exposure assumed to occur daily (indoor & outdoor) over that period. Exposure parameters are age-specific (see earlier discussion for the calculation of soil exposure rates). Subchronic Reference Dose = 0.0003 mg/kg/day from USEPA Health Effects Assessment Summary Tables (HEAST). Target Hazard Index value = 1 based upon the magnitude (10) of Uncertainty Factors and Modifying Factors used to derive the Subchronic Reference Dose.

$$[\text{OHM}]_{\text{soil}} = (\text{HI}_{\text{IH}} \times \text{RfD}_{\text{subchronic}} \times \text{C}) / ((\text{ADSIR} \times \text{RAF}_{\text{oral}}) + (\text{ADSCR} \times \text{RAF}_{\text{dermal}}))$$

$$[\text{OHM}]_{\text{soil}} = (1 \times 0.0003 \times 10^6) / ((5.3 \times 1) + (87.9 \times 0.2))$$

$$[\text{OHM}]_{\text{soil, noncancer}} = 13.1 \text{ mg/kg}$$

The Imminent Hazard Soil Trigger Level for Methyl Mercury is based upon the potential non-cancer risks: 13.1 mg/kg. No cancer risk-based concentration was calculated as methyl mercury is not considered to be carcinogenic. Expressed in one significant figure, 13.1 rounds to 10 mg/kg (ppm).

Methyl Mercury I.H. Trigger, Soil = 10 mg/kg

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Polychlorinated Biphenyls (PCBs)

BASIS: Lowest Risk-Based Concentration:

Cancer: 30 year residential exposure, ages 0 to 30. Exposure parameters are age-specific and normalized to body weight. See Background Documentation for Numerical Standards (1/4/93), Appendix A, for the calculation of soil exposure rates. Target risk level = one-in-ten thousand (10^{-4}). Carcinogenic Slope Factor = 7.7 per mg/kg/day from USEPA Integrated Risk Information System (IRIS).

$$[\text{OHM}]_{\text{soil}} = (\text{ELCR} \times \text{C}) / (\text{CSF} \times ((\text{RAF}_{\text{oral}} \times \text{NLADSIR}) + (\text{RAF}_{\text{dermal}} \times \text{NLADSCR})))$$

$$[\text{OHM}]_{\text{soil}} = (10^{-4} \times 10^6) / (7.7 \times ((1 \times 0.41) + (0.067 \times 7.3)))$$

$$[\text{OHM}]_{\text{soil, cancer}} = 14.4 \text{ mg/kg}$$

Noncancer: A 5 month (subchronic) residential exposure for a child age 5 < 6 years. Exposure assumed to occur daily (indoor &

outdoor) over that period. Exposure parameters are age-specific (see earlier discussion for the calculation of soil exposure rates). Subchronic Allowable Daily Intake = 0.00002 mg/kg/day from Chronic Oral Allowable Daily Intake For Aroclors (Memorandum to Carol Rowan West from Marion Harnois, ORS, 5/10/93). Target Hazard Index value = 10 based upon the number of Uncertainty Factors and Modifying Factors used to derive the Allowable Daily Intake.

$$[\text{OHM}]_{\text{soil}} = (\text{HI}_{\text{IH}} \times \text{RfD}_{\text{subchronic}} \times \text{C}) / ((\text{ADSIR} \times \text{RAF}_{\text{oral}}) + (\text{ADSCR} \times \text{RAF}_{\text{dermal}}))$$

$$[\text{OHM}]_{\text{soil}} = (10 \times 0.00002 \times 10^6) / ((5.3 \times 1) + (87.9 \times 0.067))$$

$$[\text{OHM}]_{\text{soil, noncancer}} = 17.9 \text{ mg/kg}$$

The Imminent Hazard Soil Trigger Level for PCBs is based upon the potential cancer risks: 14.4 mg/kg < 17.9 mg/kg. Expressed in one significant figure, 14.4 rounds to 10 mg/kg (ppm).

$$\text{PCBSI.H. Trigger, Soil} = 10 \text{ mg/kg}$$

APPENDIX E

**REPORTABLE CONCENTRATIONS
IN GROUNDWATER AND SOIL**

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APPENDIX E

REPORTABLE CONCENTRATIONS (RCs) IN GROUNDWATER AND SOIL

1.0 Introduction

The goal of this Appendix is to offer a brief explanation of the Reportable Concentrations (RCs) contained in the Massachusetts Contingency Plan (MCP; 310 CMR 40). The derivation and meaning of the RCs will be discussed, as will their application under the MCP.

2.0 Description

The Reportable Concentrations (RCs) are levels of an oil or hazardous material that, when found in soil or groundwater, trigger the reporting requirements explained in Subpart C of the Massachusetts Contingency Plan. Reportable Concentrations are extrapolated from one of two possible sources. For the 104 chemicals most frequently reported at sites in Massachusetts, the RCs have been extrapolated from the Method 1 Cleanup standards contained in Subpart I of the MCP. The remaining RCs listed in the Massachusetts Oil and Hazardous Material List (MOHML; 310 CMR 40.1600), are derived from Massachusetts Reportable Quantities (RQs) which are assigned to oil/hazardous material (OHM) by the MA DEP. [Note that these values are different from federal RQs assigned under CERCLA.] The Reportable Concentrations are a new and important part of the MCP and readers should refer to the regulations for their specific applicability.

When looking up the Reportable Concentrations in the MOHML one sees four RCs for each compound listed. The RCs are both media and exposure specific. Two of the RCs are applicable to groundwater: RCGW-1 and RCGW-2. (The acronym RCGW stands for Reportable Concentration in Ground Water.) The other pair of RCs is applicable to soil concentrations: RCS-1 and RCS-2 (RCS representing Reportable Concentrations in Soil). The RCGW-1 and RCS-1 numbers are applicable in situations where the potential for exposure to the soil or groundwater in question is high; conversely, RCGW-2 and RCS-2 numbers are applicable in situations where the potential for exposure is lower. All the Reportable concentrations are given in parts per million, the groundwater numbers are given as milligrams contaminant per liter of water (mg/l) and the soil numbers are stated as milligrams contaminant per kilogram of soil (mg/kg).

The use of the Reportable Concentrations listed in Table E-1 and in the MOHML (of which Table E-1 is a subset) is explained in detail in Subpart C (310 CMR 40.0300) of the MCP. The exceedance of an applicable RC (applicable in terms of media and exposure potential) triggers the 120-day notification requirement described in 310 CMR 40.0315, although there are circumstances under which 2-hour (310 CMR 40.0311) or 72-hour (310 CMR 40.0313) notification is required. These reporting requirements are complex and the Department encourages people to become familiar with the regulations in Subpart C before the need to notify arises.

3.0 Derivation

As previously stated, the Reportable Concentrations are developed from two different sources. For those chemicals found most frequently at Massachusetts sites, (i.e. the 104 chemicals listed in Table E-1) the RCs are extrapolated from the Method 1 Cleanup standards listed in Subpart I of the MCP, and which are explained in greater detail in the body of this document. As a result of being based on the Method 1 numbers, these RCs are closely correlated with levels of risk of harm to health, public welfare and the environment.

For these 104 chemicals the RCs in groundwater and soil are derived from the Method 1 Groundwater and Soil standards using the following strategy:

RCGW-1
Derived by choosing the **lowest** of the following Method 1 standards:

- * GW-1
- * GW-2
- * GW-3

RCGW-2
Derived by choosing the **lowest** of the following Method 1 standards:

- * GW-2
- * GW-3

RCS-1
Derived by choosing the **lowest** of the following Method 1 standards:

- * S-1/GW-1
- * S-1/GW-2
- * S-1/GW-3
- * S-2/GW-1
- * S-3/GW-1

RCS-2
Derived by choosing the **lowest** of the following Method 1 standards:

- * S-2/GW-2
- * S-2/GW-3
- * S-3/GW-2
- * S-3/GW-3

(Also see figure E- 1 for a description of this process.)

It is important to note that while these Reportable Concentrations are extrapolated from the Method 1 Cleanup Standards, the two sets of numbers are **different** and their application and use are **distinct**, as explained in Subpart C and Subpart I of the MCP. The RCs are triggers for reporting and are meant to be applied early when a limited amount of information about the site is available. The Reportable Concentration is to be compared to the highest concentration found at a site; this means that only one value need to be above the RC to trigger the reporting requirement . In contrast, the Method 1 Cleanup Standards are used to determine the need for remediation and are used when the site has been better characterized and more information has been collected. The Method 1 Cleanup Standards are based on exposure point concentrations, which may be

averages or weighted averages of a number of values (310 CMR 40.0973(3)). Therefore the need to remediate is not dependent on only one value exceeding a cleanup standard.

While it is true that the Reportable Concentrations and the Method 1 Cleanup Standards are distinct in meaning and application, it is often the case that if the RC has been exceeded that the applicable cleanup standard has been exceeded as well and remediation may be required. But it is important to note that being below an RC does not necessarily mean that a site poses no risk: it can only be concluded that no notification is required at this time. Notification and possibly remediation may be required if/when more is known about the site.

For the large number of chemicals listed on the MOHML which do not have Method 1 Standards a different strategy had to be applied to develop Reportable Concentrations. These RCs are based on the Reportable Quantities (RQs) assigned by the Massachusetts DEP to the compounds listed on the MOHML and are, therefore, general indicators of relative risk. Thus, for the majority of compounds listed on the MOHML the following method is used to extrapolate the listed RCs:

<u>MA DEP RQ (lbs.)</u>	<u>RCGW-1*</u>	<u>RCGW-2*</u>	<u>RCS-1*</u>	<u>RCS-2*</u>
1	0.1	1	10	100
5	0.5	5	50	500
10	1	10	100	1000
50	5	50	500	5000
100	10	100	1000	10000

*RCs are given in parts per million: mg/l for groundwater, mg/kg for soil

The application of all RCs is described in detail in Subpart C of the MCP.

4.0 Implications

Reportable Concentrations are ONLY triggers for reporting under the Massachusetts Contingency Plan and any other use of these numbers is not sanctioned by the Massachusetts Department of Environmental Protection.

Reportable Concentrations are NOT cleanup standards. The Method 1 Cleanup Standards are a distinct and separate list of numbers and their use is described in detail in Subpart I of the MCP.

Reportable Concentrations are NOT "No Risk" levels. Sites with reported concentrations of OHMs below RCs do not require notification to the Department but may pose a significant risk. Information gathered at a later date or through the DEP's Site Discovery Program may result in the need for notification and/or remediation at a site.

Reportable Concentrations are NOT screens to eliminate Contaminants of Concern from a Risk Assessment. The acceptable way to perform a Human Health and Ecological Risk Assessment is described in greater detail in the Guidance for Disposal Site Risk Characterization issued by the DEP's Office of Research and Standards and the Bureau of Waste Site Cleanup (revised draft expected in the Spring of 1994).

RELATIONSHIPS BETWEEN THE MCP METHOD 1 STANDARDS & THE REPORTABLE CONCENTRATIONS (RCs) FOR GROUNDWATER AND SOIL *

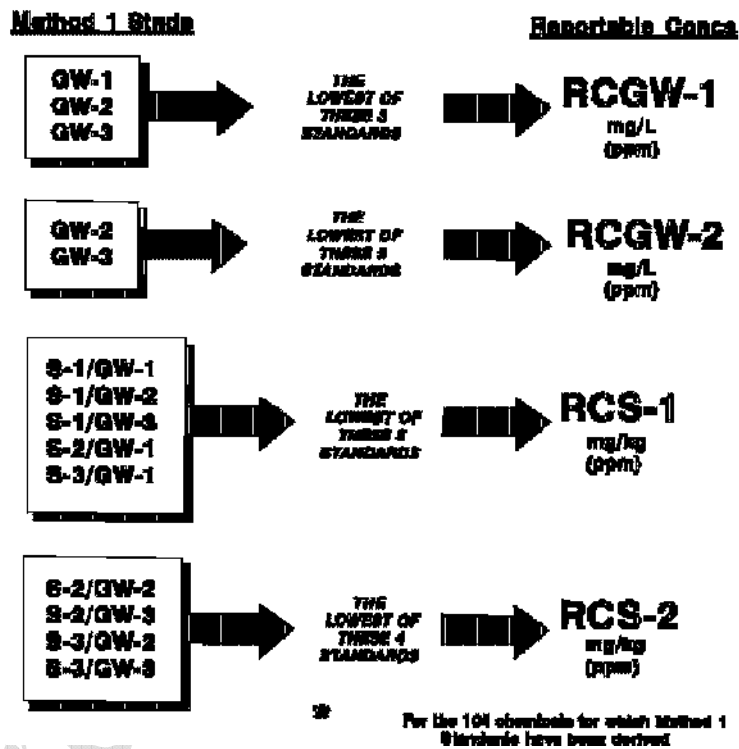


Figure E-1

Table E-1

REPORTABLE CONCENTRATIONS GROUNDWATER	(RCs) IN AND SOIL			
A Subset of Chemicals Extracted	from 310 CMR 40.1600 Material List (MOHML)			
The Massachusetts Oil and Hazardous	and the MOHML for additional chemicals.			
See MCP Subpart C for the use of these RCs	and the MOHML for additional chemicals.			
OIL OR HAZARDOUS MATERIAL	RCGW-1 mg/L (ppm)	RCGW-2 mg/L (ppm)	RCS-1 mg/kg (ppm)	RCS-2 mg/kg (ppm)
ACENAPHTHENE	0.02	2	20	2000
ACENAPHTHYLENE	0.3	2	100	800
ACETONE	3	50	3	60
ALDRIN	0.0005	0.0005	0.03	0.04
ANTHRACENE	0.6	0.6	1000	1000
ANTIMONY	0.006	0.3	10	40
ARSENIC	0.05	0.4	30	30
BENZENE	0.005	2	10	60
BENZO(a)ANTHRACENE	0.0002	0.005	0.7	0.7
BENZO(a)PYRENE	0.0002	0.002	0.7	0.7
BENZO(b)FLUORANTHENE	0.0002	0.007	0.7	0.7
BENZO(g,h,i)PERYLENE	0.0001	0.0001	30	30
BENZO(k)FLUORANTHENE	0.0002	0.0004	0.7	0.7
BERYLLIUM	0.004	0.05	0.4	0.8
BIPHENYL, 1,1-	0.4	4	1	10
BIS(2-CHLOROETHYL)ETHER	0.03	0.1	0.7	0.7
BIS(2-CHLOROISOPROPYL)ETHER	0.03	0.4	0.7	3
BIS(2-ETHYLHEXYL)PHTHALATE	0.006	0.03	100	300
BROMODICHLOROMETHANE	0.005	50	0.1	20
BROMOFORM	0.005	0.8	0.1	20
BROMOMETHANE	0.002	0.002	3	3

CADMIUM	0.005	0.01	30	80
CARBON TETRACHLORIDE	0.005	0.02	1	4
CHLORDANE	0.002	0.002	1	2
CHLOROANILINE, p-	0.03	50	1	30
CHLOROBENZENE	0.1	0.5	8	40
CHLOROFORM	0.005	0.4	0.1	10
CHLOROPHENOL, 2-	0.01	40	0.7	20
CHROMIUM (TOTAL)	0.1	2	1000	2500
CHROMIUM (III)	0.1	2	1000	2500
CHROMIUM (VI)	0.05	0.1	200	600
CHRYSENE	0.0002	0.003	0.7	0.7
CYANIDE	0.01	0.01	100	100
DIBENZO(a,h)ANTHRACENE	0.0002	0.0003	0.7	0.7
DIBROMOCHLOROMETHANE	0.005	50	0.09	20
DICHLOROBENZENE, 1,2- (o-DCB)	0.6	8	100	500
DICHLOROBENZENE, 1,3- (m-DCB)	0.6	8	100	500
DICHLOROBENZENE, 1,4- (p-DCB)	0.005	8	2	60
DICHLOROBENZIDINE, 3,3'-	0.08	2	1	1
DICHLORODIPHENYL DICHLOROETHANE, P,P'- (DDD)	0.0001	0.006	2	3
DICHLORODIPHENYLDICHLOROETHYLENE, P,P'- (DDE)	0.0001	0.02	2	2
DICHLORODIPHENYLTRICHLOROETHANE, P,P'- (DDT)	0.0003	0.0003	2	2

DICHLOROETHANE, 1,1-	0.07	9	3	400
DICHLOROETHANE, 1,2-	0.005	0.02	0.05	0.2
DICHLOROETHYLENE, 1,1-	0.001	0.001	0.1	0.1
DICHLOROETHYLENE, CIS-1,2-	0.07	50	2	500
DICHLOROETHYLENE, TRANS-1,2-	0.1	50	4	1000
DICHLOROPHENOL, 2,4-	0.01	4	10	90
DICHLOROPROPANE, 1,2-	0.005	0.009	0.1	0.2
DICHLOROPROPENE, 1,3-	0.0005	0.005	0.01	0.1
DIELDRIN	0.0001	0.0001	0.03	0.04
DIETHYL PHTHALATE	0.03	0.03	0.7	0.7
DIMETHYL PHTHALATE	0.03	0.03	0.7	0.7
DIMETHYLPHENOL, 2,4-	0.1	20	0.7	10
DINITROPHENOL, 2,4-	0.2	2	3	6
DINITROTOLUENE, 2,4-	0.03	2	0.7	2
DIOXIN	3e-08	1e-07	4e-06	6e-06
ENDOSULFAN	0.0001	0.0001	0.05	0.05
ENDRIN	0.002	0.005	0.6	1
ETHYLBENZENE	0.7	4	80	500
ETHYLENE DIBROMIDE	0.00002	0.003	0.005	0.02
FLUORANTHENE	0.1	0.1	600	600
FLUORENE	0.3	1	400	1000

HEPTACHLOR	0.0004	0.001	0.1	0.2
HEPTACHLOR EPOXIDE	0.0002	0.002	0.06	0.09
HEXACHLOROBENZENE	0.001	0.04	0.7	0.8
HEXACHLOROBUTADIENE	0.0006	0.0006	3	3
HEXACHLOROCYCLOHEXANE, GAMMA (gamma-HCH)	0.0002	0.0008	0.1	0.5
HEXACHLOROETHANE	0.008	0.01	6	10
INDENO(1,2,3-cd)PYRENE	0.0002	0.0003	0.7	0.7
LEAD	0.02	0.03	300	600
MERCURY	0.001	0.001	10	60
METHOXYCHLOR	0.002	0.002	30	30
METHYL ETHYL KETONE	0.4	50	0.3	40
METHYL ISOBUTYL KETONE	0.4	50	0.5	70
METHYL MERCURY	0.0001	0.0001	7	20
METHYL TERT BUTYL ETHER	0.7	50	3	200
METHYLENE CHLORIDE	0.005	50	0.1	200
METHYLNAPHTHALENE, 2-	0.01	3	0.7	7
NAPHTHALENE	0.02	6	4	1000
NICKEL	0.08	0.08	300	700
PENTACHLOROPHENOL	0.001	0.08	5	10
PHENANTHRENE	0.05	0.05	100	100
PHENOL	4	30	60	500

POLYCHLORINATED BIPHENYLS	0.0003	0.0003	2	2
PYRENE	0.08	0.08	500	500
SELENIUM	0.05	0.08	300	2500
SILVER	0.007	0.007	100	200
STYRENE	0.1	0.9	2	20
TETRACHLOROETHANE, 1,1,1,2-	0.005	0.006	0.4	0.5
TETRACHLOROETHANE, 1,1,2,2-	0.002	0.02	0.02	0.2
TETRACHLOROETHYLENE	0.005	3	0.5	300
THALLIUM	0.002	0.4	8	30
TOLUENE	1	6	90	500
TOTAL PETROLEUM HYDROCARBONS	1	50	500	2500
TRICHLOROBENZENE, 1,2,4-	0.07	0.5	100	800
TRICHLOROETHANE, 1,1,1-	0.2	4	30	500
TRICHLOROETHANE, 1,1,2-	0.005	20	0.3	3
TRICHLOROETHYLENE	0.005	0.3	0.4	20
TRICHLOROPHENOL, 2,4,5-	0.1	0.1	2	2
TRICHLOROPHENOL 2,4,6-	0.01	10	3	60
VINYL CHLORIDE	0.002	0.002	0.3	0.3
XYLENES	6	6	500	500
ZINC	0.9	0.9	2500	2500

APPENDIX F

**DEVELOPMENT OF
DILUTION/ATTENUATION FACTORS
(DAFs)
FOR THE LEACHING-BASED
SOIL STANDARDS**

DEVELOPMENT OF DILUTION/ATTENUATION FACTORS (DAFs) FOR THE LEACHING-BASED SOIL STANDARDS

INTRODUCTION

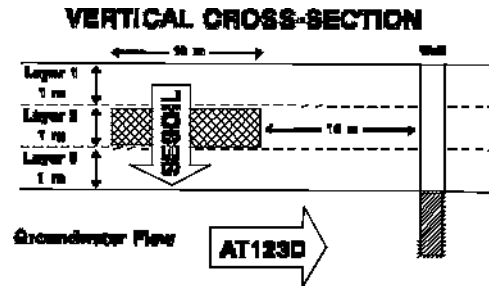
The Massachusetts Department of Environmental Protection has developed dilution attenuation factors (DAFs) in order to establish soil cleanup criteria for the protection of groundwater from leaching of residual contaminants in soil. DEP has adopted the modeling approach utilized by the State of Oregon in a similar process. This report describes the model and its application toward the development of DAFs for Massachusetts for a limited number of compounds of concern, and the subsequent development of one regression algorithm that relates DAFs developed by Oregon to those applicable in Massachusetts, and another algorithm that relates DAFs to chemical specific parameters. The pathway to groundwater is only one consideration in the final determination of an acceptable soil cleanup level.

THE OREGON MODEL

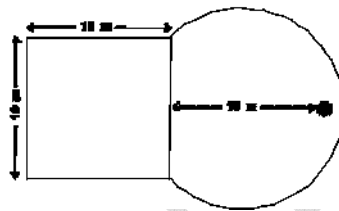
The Oregon model (Anderson, 1992) assumes a generic setting for a release of contaminant in the unsaturated zone and then applies the combination of SESOIL and AT123D models to estimate impact of the initial soil loading on a receptor assumed directly downgradient of the site via the groundwater pathway. The SESOIL and AT123D models, while previously individually developed (see References, Bonazountas, 1984 and Yeh, 1981), are a part of the risk assessment Graphical Exposure Modeling System (GEMS) developed by USEPA. A pc-based version of this (PCGEMS) was developed for USEPA by General Sciences Corporation (1989). The two models can now be linked so that SESOIL can pass leachate loadings to the saturated zone AT123D model.

The Oregon model's site setting (see Figure 1) assumes a 3-meter thick unsaturated zone, divided into three 1-meter layers. Contamination is initially released in the middle layer, as might occur for a leaking tank or for a residual contaminant remaining after some remedial excavation with clean cover backfill, and is uniformly distributed in this layer over a 10 meter by 10 meter area. The unsaturated zone and aquifer are assumed to be the same sandy soil with uniform properties. The upper and lower unsaturated zone layers are initially clean, as is the aquifer.

FIGURE 1
CONCEPTUAL SETTING



HORIZONTAL CROSS-SECTION



Source: Anderson (1991)

SESOIL inputs include the soil type parameters, chemical properties, application rates, and the climatic conditions of the area. The model is run as a transient monthly estimator of leachate volumes and concentrations. Initially, no other transport mechanisms other than leaching, partitioning, and volatilization were considered. Oregon used default values in SESOIL for Portland Oregon climatic conditions, but distributed total precipitation uniformly over the year.

SESOIL was initially found to overestimate losses via volatilization. A parameter, the volatilization fraction (VOLF), was introduced to allow adjustment of losses through this pathway and allow a site-specific calibration. This factor may be varied in time and space. The Oregon study used a uniform VOLF factor of 0.2, based on consultation with a panel of experts. One other soil-related parameter is the disconnectedness index. This parameter varies for and within soil types. Two values are given as SESOIL defaults, and the larger, 7.5, has been used in the simulations. An increase in this parameter appears to result in a higher soil moisture, lower leachate rates, and somewhat lower DAFs (i.e., is more conservative) for the compounds run.

AT123D inputs include general aquifer properties, source configuration, loadings to groundwater, soil partition coefficients, and dispersivity values. The aquifer is assumed to be infinitely wide and thick. The pc-based version of AT123D accepts monthly transient loading rates calculated by SESOIL, and also provides a preprocessor for input file preparation and editing. In utilizing the model, the center of the 10 by 10 meter source area is assumed to be at coordinates 0,0,0. The positive x-axis is in the direction of flow. Calculated concentrations are maximum along the x-axis ($y=0$) and at the water table surface ($z=0$). Since the receptor is assumed to be 10 meters from the downgradient edge of the source area, the concentration at $x=15$, $y=0$, and $z=0$ represents the receptor location. Oregon used longitudinal, transverse, and vertical dispersivities of 20m, 2m, and 2m, respectively. These values seem high for a sandy aquifer, but the values have been retained to be consistent with the Oregon base values and to be protective of the Commonwealth's sensitive aquifers on Cape Cod. DAFs are proportional to the dispersivities, particularly sensitive to the vertical dispersivity.

Oregon ran the model for 10 indicator compounds and then developed a multiple linear regression model relating the DAF to the organic partition coefficient (K_{oc}) and the Henry's Law constant (H) to provide preliminary DAFs for sixty other organic compounds. Soil cleanup levels were generated based on the regression algorithm and a safe drinking water level for each compound. In some cases, risk based levels determined by other pathways were lower than the levels required to protect groundwater. In these instances, the lower value was selected as the soil target level. A similar approach was taken to develop the MCP Method 1 Standards, as described in Section 5.3.

SIMULATIONS FOR MASSACHUSETTS

The approach taken to develop DAFs for Massachusetts was to determine the effect that varying the location (changing the climatic conditions from Portland, Oregon to Boston, Massachusetts in SESOIL) would have on the Oregon calculated DAFs. If the model system was essentially linear with respect to loading, then DAFs already calculated for Oregon would be directly related to DAFs appropriate for Massachusetts, and the general algorithm developed by Oregon (with coefficients adjusted) could also be used to estimate DAFs for other compounds. To this end, model runs were made using the Oregon input values for SESOIL and AT123D with the exception of climate parameter values. Eight indicator compounds were selected: benzene, toluene, ethylbenzene, o-xylene, trichloroethene, tetrachloroethene, 1,1,1-trichloroethane, and naphthalene.

The input values for SESOIL are shown in Tables F-1 through F-4, and those for AT123D are shown on Table F-5. Depending on the mobility of the compound through the transport pathway, model runs varied from 2 years to 6 years as necessary to determine the maximum concentration attained at the receptor location for a specific compound. A point to consider in the adoption of the Oregon values, or adjustments to them, is the need to agree with the physio-chemical parameters that were used to generate the DAFs. Even in the eight indicator compounds selected, various accepted databases provide some widely varying values for S, H and K_{oc} . For example, for PCE, H is reported with an order of magnitude difference, and values of K_{oc} and solubility differing by a factor of 2 are reported for ethylbenzene in the literature.

Output concentrations at the selected receptor location demonstrated a cyclical nature due to seasonal variations in precipitation and net recharge. Maximum concentrations were not always attained in the first cycle due to seasonal variability. However, the model output appeared to be

linear with respect to the initial loading, allowing soil cleanup levels to be estimated based on the linear DAF approach. Table F-6 shows the model-based DAFs for Oregon and Massachusetts, and also, based on listed safe drinking water levels and the estimated DAFs for Massachusetts, what soil target levels would be for the eight indicator compounds run.

**TABLE F-1
CLIMATE PARAMETER VALUES
FOR THE SESOIL MODEL**

Default climate values for Boston as contained in the SESOIL model. Latitude = 42 degrees.

**TABLE F-2
SOIL PARAMETER VALUES
FOR THE SESOIL MODEL**

Intrinsic permeability = $1 \times 10^{-7} \text{ cm}^2$
Source area = $1,000,000 \text{ cm}^2$
Porosity = 0.3
Disconnectedness index = 7.5
Soil bulk density = 1.5 gm/cm^3
Soil organic carbon = 0.1%

Layer 1 thickness = 100 cm
Layer 2 thickness = 100 cm
Layer 3 thickness = 100 cm
No further sublayering specified

Clay content = 0%

All other parameters set to zero except those to indicate uniform parameters in all layers.

**TABLE F-3
APPLICATIONS DATA
FOR SESOIL MODEL**

Application month = October only
layer = 2
rate = 1500 microgm/cm ²
year = 1 only
Based on the area, thickness and bulk density, this produces an initial concentration of 10 ppm. No other sources are added.
Volatile fraction (VOLF)= 0.02
Uniform in time and space.
All other parameter values set to zero.

**TABLE F-4
CHEMICAL DATA FOR SESOIL MODEL**

Compound	MW	K _{oc} ml/g	S mg/L	H atm-m ³ /mol	DA cm ² /sec
benzene	78	83	1780	0.0055	0.109
ethylbenzene	106	575	161	0.00343	0.093
toluene	92	270	535	0.00668	0.100
o-xylene	106	302	171	0.00527	0.093
TCE	131	124	1100	0.00912	0.083
PCE	166	468	200	0.00204	0.075
1,1,1-TCA	133	157	730	0.0231	0.080
naphthalene	128	1288	31	0.00118	0.085

MW = molecular weight
K_{oc} = organic carbon partition coefficient
S = solubility in water
H = Henry's Law constant
DA = diffusion coefficient in air

**TABLE F-5
AT123D MODEL INPUT PARAMETER VALUES**

Soil bulk density	= 1.5 g/cc
Porosity	= 0.3
Hydraulic conductivity	= 0.5 m/hr
Hydraulic gradient	= 0.005
Longitudinal dispersivity	= 20.0 m
Transverse dispersivity	= 2.0 m
Vertical dispersivity	= 2.0 m
Loading (kg/hr) passed by SESOIL link program	
Distribution coefficient = K_{oc} * fraction organic carbon	
Source area = 10 m by 10 m, centered at 0,0	
initial z penetration = 0	
Degradation rates initially zero	

**TABLE F-6
MODEL OUTPUT DRAFT DAFS
COMPARISON AND SOIL LEVELS**

Compound	Oregon Mass DAF	Mass DAF	DRINKING WATER LEVEL mg/L	SOIL TARGET LEVEL ppm
benzene	44.4	56.5	0.005	0.28
ethylbenzene	103.5	121.1	0.700	84.8
toluene	64.5	80.6	1.000	80.6
o-xylene	65.4	83.3	10.000	833.3
TCE	65.4	76.3	0.005	0.38
PCE	73.0	86.2	0.005	0.43
1,1,1-TCA	133.2	169.2	0.200	33.8
naphthalene	207.0	222.2	0.280	62.2

STATISTICAL RELATIONSHIPS

A linear regression was run on the eight DAF data pairs with DAFs for Oregon as the independent variable. The model was :

$$DAF_{Mass} = A + B * DAF_{Oregon}$$

That is, the regression was not forced through the origin. For the eight data pairs, the equation was

$$DAF_{Mass} = 12.39 + 1.053 * DAF_{Oregon}$$

with an r of 0.99 13. Thus, over the range of data spanned by these eight compounds, the correlation appears good. Table F-7 shows a comparison of the DAFs calculated by the model and those by the linear regression equation above for the eight indicator compounds. Differences between the two methods are less than 10 percent.

A multiple linear regression algorithm for DAF(Mass) as a function of K_{oc} and H was also developed along the same lines as that developed by Oregon. This allows the calculation of DAFs for compounds for which Oregon did not consider, and which also may be used exclusively from the linear regression cited above. Two models were considered:

- (a) $DAF = A + B * H + C * K_{oc}$, and
- (b) $DAF = B * H + C * K_{oc}$.

where A, B, and C are regression coefficients. As with the Oregon analysis, it proved that the constant term was not statistically different from zero, and the simpler second model was adopted. Regression analysis yielded:

$$DAF = 6207 * H + 0.166 * K_{oc}$$

The fit here is somewhat better than the r-squared value of .956 for the Oregon model in that one compound with a large residual (carbon tetrachloride with a residual of 30) was not used here, and the average difference is much smaller with the eight compounds than for Oregon's ten. Table F-8 shows the relationship between the model DAFs and the regression expression predicted values. Only one compound varies more than 10 percent while six of the eight have percent differences less than five.

**TABLE F-7
COMPARISON BETWEEN MODEL DAFS
AND LINEAR REGRESSION DAFS
BASED ON OREGON DAFS**

Compound	Model DAF	Regr. DAF	% Difference
benzene	56.5	59.1	4.60
ethylbenzene	121.1	121.4	0.25
toluene	80.6	80.3	-0.37
o-xylene	83.3	81.3	-2.40
TCE	76.3	81.3	6.55
PCE	86.2	89.3	3.60
1,1,1-TCA	169.2	152.6	-9.81
naphthalene	222.2	230.4	3.69

**TABLE F-8
RESULTS OF THE MULTIPLE LINEAR REGRESSION
EQUATION FOR H AND KOC**

Compound	Model DAF	Predicted	% Difference
benzene	56.5	47.9	-15.2
ethylbenzene	121.1	116.7	- 3.6
toluene	80.6	86.3	7.1
o-xylene	83.3	82.8	- 0.5
TCE	76.3	77.2	1.2
PCE	86.2	90.4	4.9
1,1,1-TCA	169.2	169.4	0.1
naphthalene	222.2	221.1	- 0.5

BIODEGRADATION

It is intuitive that biodegradation may play an important role in attenuating the potential impact of residual contaminants in soils on groundwater. However, there are a great many site-specific conditions that will determine actual biodegradation rates. Further, literature values cover a wide range and the exact conditions under which they were estimated are rarely known. Literature values should be applied only with great caution to any estimation of contaminant fate and transport. In order to evaluate the potential effect of biodegradation, rate constants cited by

Howard et al (1991) were input to the model for the five compounds of the eight indicator compounds known to degrade aerobically. This eliminated the chlorinated compounds TCE, PCE, and 1,1,1-TCA. In addition, one additional rate for benzene (0.002/day from the California LUFT guidance) was also run. Four runs were made for benzene as the most critical compound, at the California rate, at the high and low rates cited by Howard and at the geometric mean of the Howard high and low rates. Only one rate, the low Howard value, was used for each of the other four compounds. The reason for this will be seen shortly.

The degradation rates in Howard appear to be high, with half lives for the BTEX compounds on the order of days. This implies that within a year, residual concentrations in soil would be reduced by biodegradation several (three to six) orders of magnitude. Table F-9 presents the results of the model runs.

For all situations except for the two lowest rates for benzene, the DAFs become huge. In essence, this indicates that only trace amounts of the contaminants ever reach the groundwater table. Soil target level estimation using large DAFs and the linear approach should be done only with extreme caution. A contaminant in the subsurface will attempt to reach equilibrium concentrations in the air, moisture and sorbed to soil. At some total concentration, equilibrium solubility in moisture would be exceeded, indicating the probable presence of free product. In this case, the linearity and basic assumptions in the model may be violated. Of further consideration are the potential toxic effects on the biological population as concentrations of the compounds increase. For these circumstances, estimation of soil target levels considering biodegradation is very difficult.

**TABLE F-9
RESULTS OF THE BIODEGRADATION RUNS**

Compound	Rate in Soil 1/day	Rate in Water 1/day	DAF
benzene	0.002	0.001 *	84.7
benzene	0.0433	0.000963	2178.
benzene	0.0775	0.00817	1.5 x 10 ⁴
benzene	0.1386	0.0693	5.7 x 10 ⁷
toluene	0.0315	0.02475	8.7 x 10 ⁶
ethylbenzene	0.0693	0.00304	1.8 x 10 ¹³
o-xylene	0.02475	0.001899	2.8 x 10 ⁵
naphthalene	0.01444	0.00269	8.6 x 10 ¹⁰

* Note: Odencrantz's article on the California LUFT parameter values did not cite a rate for water. This was assumed here to be half that in soil. Note that not much more degradation occurs in the aquifer due to the rapid travel time to the receptor of about 11 to 12 days (large longitudinal dispersivity and low retardation).

SENSITIVITY

A detailed sensitivity analysis was not done at this point in time. However, Oregon did perform some sensitivity analyses, and sensitivity of these models as applied in California's LUFT program is discussed in another article (Odenchantz, et al, 1992)

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Yeh, G. 1981. AT123D: Analytical Transient One-, Two-, and Three- Dimensional Simulation of Waste Transport in the Aquifer System. Oak Ridge National Laboratory. ORNL-5602.

APPENDIX G

**SELECTION OF PRACTICAL QUANTITATION LIMITS
FOR METHOD 1 CHEMICALS**

Archived Document

APPENDIX G

Selection of Practical Quantitation Limits for Method 1 Chemicals

The majority of the Practical Quantitation Limits (PQL) for the MCP Method 1 chemicals are taken from one of three references on USEPA-approved laboratory methods. The references are as follows:

- USEPA Test Methods for Evaluating Solid Waste, SW-846, Third Edition (Revision 0), November 1986 (Reference 1)
- USEPA Methods for the Determination of Organic Compounds in Drinking Water, EPA-600/4-88/039, December 1988 (Revised July 1991) (Reference 2)
- Guide To Environmental Analytical Methods, Robert E. Wagner, Editor, Genium Publishing Corporation, 1992 (Reference 3)

The specific method on which the PQL is based is referenced in the two tables of PQLs in Section 3.1 (the explanation of the references follows Table 2-1). The references provide a method number. Below is a description of the various methods that appear in the references. From USEPA Test Methods for Evaluating Solid Waste (often referred to as SW-846), PQLs were excerpted from the following methods:

Method 8240: Volatile Organics by Gas Chromatography/Mass Spectrometry (GC/MS): Packed Column Technique

Method 8080: Organochlorine Pesticides and Polychlorinated Biphenyls by Gas Chromatography

Method 8270: Semivolatile Organic Compounds by Gas Chromatography/Mass Spectrometry (GC/MS): Capillary Column Technique

Method 6010: Inductively Coupled Plasma Atomic Emission Spectroscopy

Method 7470: Mercury in Liquid Waste/Cold Vapor Technique

From the USEPA's Methods for the Determination of Organic Compounds in Drinking Water, PQLs were excerpted from the following methods:

Method 524.1: Measurement of Purgeable Organic Compounds in Water by Packed Column Gas Chromatography/Mass Spectrometry

Method 524.2: Measurement of Purgeable Organic Compounds in Water by Capillary Column Gas Chromatography/Mass Spectrometry

Method 525.1: Determination of Organic Compounds in Drinking Water by Liquid-Solid Extraction and Capillary Column Gas Chromatography/Mass Spectrometry

From the Guide to Environmental Analytical Methods, a reference that condenses information in SW-846, EPA 200, 500, and 600 Series; Standard Methods; and the Contract Laboratory Program (CRP) into one book, PQLs were excerpted from the following methods:

Method 335: Determination of Total and Amenable Cyanide

Method 200.7: Atomic Absorption Methods

Method 508: Drinking Water Method for Pesticides: GC/ECD

Method 625: Priority Pollutants in Wastewater: Base/Neutrals, Acids, and Pesticides: GC/GC/MS

Method-Specific Adjustments

For certain methods, the PQL was not listed and had to be calculated from a Method Detection Limit (MDL). For the analysis of compounds in drinking water, sometimes a range of PQLs was provided because the method allowed for variations in laboratory methodologies or equipment. The specific assumptions that were made in selecting the PQL that appears in the Section 3.1 tables are discussed below under the various laboratory methods.

Methods 8270 and 8240:

The PQLs in the Section 3.1 tables are as listed in SW-846. No adjustments were necessary.

Method 8080:

The PQLs in the Section 3.1 tables were calculated from the Method Detection Limits provided in Table 1 of Method 8080 in (Reference 1). A formula is given in Method 8080 to calculate PQLs from MDLs. It is as follows:

$$\text{PQL} = \text{MDL (Table 1)} \times \text{Factor (Table 2)}$$

For soil PQLs (in ug/kg), the factor in Table 2 that was used as a multiplier is 670, for low-level soil by sonication with GPC cleanup. For water PQLs, a factor of 10 was used as a multiplier.

Method 6010:

For compounds analyzed for using Method 6010, estimated instrumental detection limits are given in units of ug/l in Table 1 of Reference 1. Estimated instrumental detection limits are equivalent to PQLs. For water PQLs, the PQL was simply extracted from Table 1. For soil PQLs, a water-to-soil conversion factor was applied to the estimated detection limit to arrive at a PQL in units of mg/kg. The conversion factor was equal to 0.2; in other words, the estimated detection limit in ug/l was multiplied by 0.2 to arrive at a PQL in mg/kg. The conversion factor accounts for soil sample preparation procedures (in which one gram of soil is digested in 200 mL of water) and a units conversion (from ug/l to mg/kg).

Methods 524.1, 524.2 and 525.1 are used to analyze for compounds in drinking water; they are part of EPA's 500 series for organic compounds in drinking water.

Method 524.1:

For compounds analyzed for using Method 524.1, MDLs are reported in Table 3 of Method 524.1 (in Reference 2). The PQL was assumed to be equal to five times the MDL, an assumption supported in Standard Methods for the Examination of Water and Wastewater, 17th edition, 1989.

Method 524.2:

Analyzing for purgeable organics using this method can be done using two different laboratory setups: the first is a wide bore capillary column (Table 4 in Method 524.2) and the second is a cryogenic trapping option and a narrow bore capillary column (Table 5 in Method 524.2). Both tables appear in Reference 2. Because laboratories analyzing samples from 21E sites could use either technique, PQLs were calculated for both techniques and the higher of the two PQLs was selected for the development of the Method 1 standards. The higher of the two PQLs was chosen because either technique is acceptable and choosing the higher allows for both techniques to be used. (Both Table 4 and 5 report MDLs; so PQLs were calculated as five times the MDL.)

Method 525.1:

MDLs are provided in Method 525.1 Tables 4 and 6 in Reference 2. As with Method 524.2, two laboratory techniques are allowable under Method 525.1, one involves an ion trap mass spectrometer and the other involves a magnetic sector mass spectrometer. Both sets of PQLs were calculated (as five times the MDL) and the higher of the two PQLs for a given chemical was selected as the representative PQL for that method.

Method 335:

An MDL for cyanide is provided in EPA Method 335 in Reference 3. A PQL was estimated as five times the MDL.

Method 200.7:

Estimated instrumental detection limits are provided in Table 1 for Method 200.7 (in Reference 3). These are equivalent to PQLs.

Method 508:

Estimated detection limits (EDLs) are reported in Table 2 for Method 508. These are defined in a footnote to the table as being equivalent to MDLs. Therefore, PQLs were estimated as five times the EDLs.

Comments on PQLs for Specific Chemicals

For a few chemicals, certain assumptions were made in the calculation or identification of a PQL. These are listed below:

- Because o-xylene and p-xylene co-elute in Method 524.1, the PQL for xylenes in water is the sum of the individual PQLs for these two compounds.
- The PQL for trans-1,2-dichloroethylene was assumed to be the PQL for 1,2-dichloroethylene (mixed).