Commonwealth of Massachusetts
Executive Office of Energy & Environmental Affairs

Department of Environmental Protection

One Winter Street Boston, MA 02108 • 617-292-5500

Charles D. Baker
Governor

Karyn E. Polito
Lieutenant Governor

Matthew A. Beaton
Secretary

Martin Suuberg
Commissioner

MCP Numerical Standards

Reformatted December 2017

The development of chemical-specific cleanup standards for use under the Massachusetts Contingency Plan (MCP) represents an important piece of the effort to streamline the site assessment and remediation program. The MCP Numerical Standards provide a simple means to determine whether remediation is necessary at a site and when no further remedial response action is necessary.

While the MCP retains site-specific risk assessment as an optional means (Method 3) to establish the need for remediation and to determine cleanup goals, the time and cost of preparing such assessments may not be warranted at many of the M.G.L. c.21E sites. Promulgated standards (Method 1) provide an option that is simple to use and results in predictable outcomes. The Department also offers a hybrid methodology (Method 2) that allows limited modification of the Method 1 Standards based upon site-specific information. All three Methods address the potential risk of harm to health, public welfare and the environment. Risk to safety is considered separately.

In addition to the promulgated Method 1 cleanup standards, the MCP contains other lists of numerical values. Upper Concentration Limits (UCLs) are used under Risk Characterization Methods 2 and 3. Reportable Quantities (RQs) and Reportable Concentrations (RCs) are used to determine notification requirements.

This information is available in alternate format. Contact Michelle Waters-Ekanem, Director of Diversity/Civil Rights at 617-292-5751.
TTY# MassRelay Service 1-800-439-2370
MassDEP Website: www.mass.gov/dep
Printed on Recycled Paper

METHOD 1 STANDARDS **3**

Categories of Standards 3
MCP Numerical Standards: GW-1 4
General Methodology 4
Equations to Calculate Noncancer Risk-Based Concentrations 6
Equations to Calculate Cancer Risk-Based Concentrations 19
Input Parameters 22
MCP Numerical Standards: GW-2 25
Equations 27
MCP Numerical Standards: GW-3 32
MCP Numerical Standards: S-1 35
MCP Numerical Standards: S-2 40
Documentation for the MCP S-2 Standards 41
MCP Numerical Standards: S-3 47

METHOD 2 STANDARDS **59**

MCP Numerical Standards: Method 2 59

UPPER CONCENTRATION LIMITS (UCLS) **61**

REPORTABLE QUANTITIES AND CONCENTRATIONS **62**

Method 1 Standards

The MCP Method 1 Standards represent levels of oil or hazardous materials at which no further remedial response actions would be required based upon the risk of harm posed by these chemicals. The standards are protective of public health, public welfare, and the environment (i.e., represent a condition of "no significant risk"), given the exposures assumed, and are measurable.

Method 1 standards are, by nature, generic, and are derived in a manner to be protective at a wide range of disposal sites across the state. The use of such generic standards is one risk characterization option in the Massachusetts Contingency Plan. It is important to remember that the flexibility exists under the MCP to use more site-specific risk characterization approaches under Methods 2 and 3.

Categories of Standards

The criteria that determine the applicability of the groundwater standards are described in regulation at 310 CMR 40.0932. Click on the link below for more information on the specific groundwater standards, including the methodology to derive the standards.

Category GW-1 : Concentrations based on the use of groundwater as drinking water, either currently or in the foreseeable future.

Category GW-2 : Concentrations based on the potential for volatile material to migrate into indoor air.

Category GW-3 : Concentrations based on the potential environmental effects resulting from contaminated groundwater discharging to surface water.

The criteria that determine the applicability of the soil standards are described in regulation at 310 CMR 40.0932. Click on the link below for more information on the specific soil standards, including the methodology to derive the standards.

Category S-1 : Concentrations based on sensitive uses of the property and accessible soil, either currently or in the foreseeable future. Additional criteria are established for the protection of groundwater, based on the leaching potential of the contaminated soil.

Category S-2 : Concentrations based on property uses associated with moderate exposure and accessible soil, either currently or in the foreseeable future. Additional criteria are established for the protection of groundwater, based on the leaching potential of the contaminated soil.

Category S-3 : Concentrations based on restricted access and property with limited potential for exposure, either currently or in the foreseeable future. Additional criteria are established for the protection of groundwater, based on the leaching potential of the contaminated soil.

MCP Numerical Standards Development Spreadsheets file size1MB Updated June 2014

MCP Numerical Standards: GW-1

The MCP GW-1 groundwater standards (310 CMR 40.0974(2)) apply to groundwater that is either a current drinking water resource (e.g., within a Zone 2 of a public water supply) or a potential future source of drinking water, such as a Potentially Productive Aquifer. The criteria used to categorize groundwater as GW-1 are specified in regulation, at 310 CMR 40.0932. These standards are intended to address the potential health effects associated with the use of the groundwater, including ingestion of the water, inhalation of contaminants volatilizing from the water during showering, and dermal absorption of contaminants while in contact with the water.

Documentation for the MCP GW-1 Standards

MCP Category GW-1 Standards (310 CMR 40.0974(2)) apply to groundwater that is considered either a current or a future source of drinking water. The regulatory criteria used to determine the applicability of the GW-1 standards are described at 310 CMR 40.0932(4). This section of the MCP references definitions of "*Current Drinking Water Source Area"* and "*Potential Drinking Water Source Area"* that are found in 310 CMR 40.0006.

Drinking water standards are the most common type of environmental standard, and there are existing state and federal regulatory programs that regulate contaminant concentrations in public water supplies. In order to build upon the existing body of drinking water standards and guidelines, and to promote inter-agency consistency, the Bureau of Waste Site Cleanup has decided to adopt existing values whenever possible:

- Existing drinking water standards (Massachusetts Maximum Contaminant Limits, or MMCLs) promulgated in 310 CMR 22.00 have been adopted as MCP GW-1 standards. There are 48 such standards on the MCP GW-1 list.

- Existing drinking water guidelines developed by the MA DEP Office of Research and Standards (ORS) for the MA DEP Water Supply Program have been adopted as MCP GW-1 standards. There are 18 such standards on the MCP GW-1 list.

- MCP GW-1 standards are calculated *de novo* only for those chemicals for which MMCLs or ORS Guidelines have not been established.

General Methodology

The sequential approach taken to develop the MCP GW-1 standards is as follows:

1. Adopt an existing drinking water standard or guideline when one exists (Workbook: MCP GW.xls, sheet: GW-1, columns: B and C). If no such standard or guideline exists, follow steps 2 through 8

2. Standard toxicity information, risk assessment methodologies and odor thresholds (when available) are used to identify concentrations in water associated with:

- 20% of an allowable intake based on non-cancer health effects (Workbook: MCP GW.xls, sheet: GW-1, column: G)

- an excess lifetime cancer risk equal to one-in-one million (10-6) (Workbook: MCP GW.xls, sheet: GW-1, column: K), and

- a 50% odor recognition threshold (Workbook: MCP Toxicity.xls, sheet: Toxicity, column: AH).

3. The lowest of these three values is carried through the process.

4. A ceiling concentration of 0.005% (50,000 µg/L) is noted (Workbook: MCP Toxicity.xls, sheet: Toxicity, column: BP).

5. The lower of the concentrations identified in steps 3 and 4 is carried through the process.

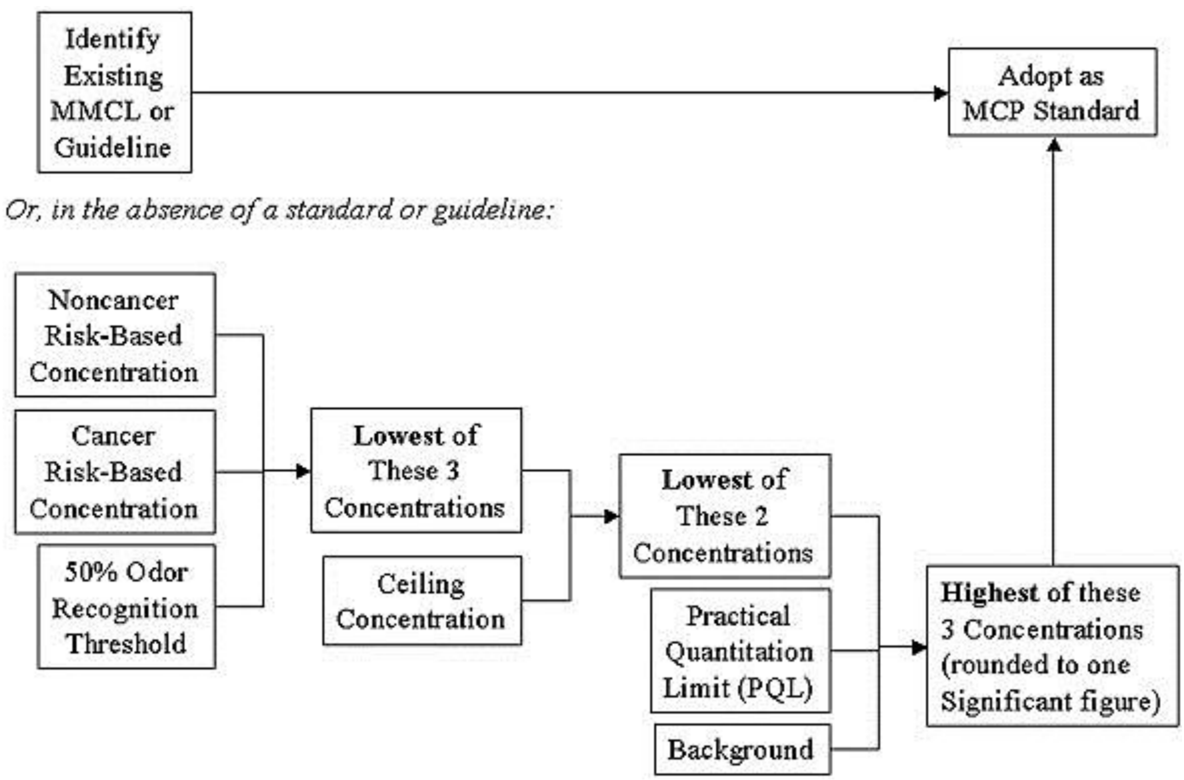
6. A Practical Quantitation Limit (PQL) for an appropriately sensitive analytical method is identified (Workbook: MCP Toxicity.xls, sheet: Toxicity, column: AO).

7. A background concentration is identified, if available (Workbook: MCP Toxicity.xls, sheet: Toxicity, column: AD).

8. The highest of the three values identified in steps 5, 6 and 7 is chosen.

9. The value identified in step 8 is rounded to one significant figure. This value is adopted as the MCP GW-1 standard.

This process is diagramed:



Equations to Calculate Noncancer Risk-Based Concentrations

The noncancer risk-based concentration of a chemical in drinking water is a function of the ingestion, inhalation and dermal contact exposures to a hypothetical residential receptor.

Ingestion

The noncancer risk-based concentration for the ingestion of drinking water is calculated using the equation:

$$[OHM]_{ing-nc} = \frac{HI \times RfD_{oral}}{DWEF_{ing-nc} \times RAF_{oral-nc}} \quad \text{(equation 1)}$$

Workbook: *MCP GW.xls*, sheet: *GW-1*, column: D

parameter		description
$[OHM]_{ing-nc}$	=	Target noncancer groundwater concentration based on ingestion (µg/L)
HI	=	Target Hazard Index level (unitless)
RfD oral	=	oral Reference Dose (mg/kg/day)
$DWEF_{ing-nc}$	=	Drinking Water Exposure Factor for noncancer, ingestion (L*mg)/(kg*ug*d)
$RAF_{oral-nc}$	=	Relative Absorption Factor for noncancer, oral exposure (unitless)

The exposure term, DWEF ing-nc, is a compilation of receptor exposure assumptions that are not chemical-specific. This factor is calculated:

$$DWEF_{ing-nc} = \frac{VI \times EF_1 \times EF_2 \times EP \times C_1 \times C_2}{BW \times AP} \quad \text{(equation 2)}$$

Workbook: *MCP GW.xls*, sheet: *DW Assumptions*, cell J18

parameter		description
$DWEF_{ing-nc}$	=	Drinking Water Exposure Factor for noncancer, ingestion (L*mg)/(kg*ug*d)
VI	=	Volume of drinking water ingested (liters/day)
EF_1	=	Exposure Frequency (days/week)
EF_2	=	Exposure Frequency (weeks/year)
EP	=	Exposure Period (years)
C_1	=	Conversion Factor (mg/µg)
C_2	=	Conversion Factor (years/day)
BW	=	Body Weight (kg)
AP	=	Averaging Period (years)

Dermal

The evaluation of dermal exposures associated with the use of drinking water is based on the U.S. EPA's Draft Dermal Exposure Guidance. For some chemicals, the estimated results fall outside the "Effective Predictive Domain". For these chemicals, the default approach recommended in the DEP's 1995 *Guidance for Disposal Site Risk Characterization* is used (equation 3b).

$$[OHM]_{derm-nc} = \frac{HI \times RfD_{oral} \times OAE_{nc}}{DWDF_{nc} \times DA_{event}}$$ (equation 3a)

$$[OHM]_{derm-nc} = \frac{HI \times RfD_{oral} \times OAE_{nc}}{DWEF_{ing-nc} \times DM}$$ (equation 3b)

Workbook: *MCP GW.xls*, sheet: *GW-1*, column: E

parameter		description
$[OHM]_{derm-nc}$	=	Target noncancer groundwater concentration based on dermal contact (µg/L)
HI	=	Target Hazard Index level (unitless)
RfD_{oral}	=	oral Reference Dose (mg/kg/day)
$DWDF_{nc}$	=	Drinking water dermal factor, noncancer ((cm^2*event)/(kg*day))
OAE_{nc}	=	Oral absorption efficiency, noncancer
DA_{event}	=	Absorbed dose per event, per exposed skin area, per unit concentration ((mg/cm^2-event)/(µg/L))
$DWEF_{ing-nc}$	=	Drinking water exposure factor, ingestion, noncancer ((L*mg)/(kg*ug*d)). See Equation 2.
DM	=	Dermal multiplier (unitless)

$$DWDF = \frac{EF_1 \times EF_2 \times EP \times SA \times C_1}{BW \times AP}$$ (equation 4)

Workbook: *MCP GW.xls*, sheet: *DW Assumptions*, cell V13

parameter		**description**
DWDF	=	Drinking water dermal factor, ((cm^2*event)/(kg*day))
EF_1	=	Exposure Frequency (events/day)
EF_2	=	Exposure Frequency (days/year)
EP	=	Exposure Period (years)
SA	=	Exposed skin surface area (cm^2)
C_1	=	Conversion Factor (years/day)
BW	=	Body Weight (kg)
AP	=	Averaging Period (years)

Non-Steady State equation for estimating dermally absorbed dose from organic chemicals in water for t event less than or equal to t*. The non-Steady state equation is used when the event duration (t event) is less than or equal to the time to reach steady state (t*).

$$DA_{event} = 2 * FA * C * Kp * Cw * \sqrt{\frac{6 * \tau * t_{event}}{\pi}}$$ (equation 5a)

Workbook: *MCP GW.xls*, sheet: *DW Dermal*, column M (columns I x L)

Steady State equation for estimating dermally-absorbed dose from organic chemicals in water for t event greater than t*. The steady state equation is used when the event duration (t event) is greater than the time to reach steady state (t*).

$$DA_{event} = FA * C * Kp * Cw * \left[\left(\frac{t_{event}}{1 + B} \right) + 2 * \tau * \left(\frac{1 + 3B + 3B^2}{(1 + B)^2} \right) \right]$$ (equation 5b)

Workbook: *MCP GW.xls*, sheet: *DW Dermal*, column M (columns I x L)

Equation for estimating dermally-absorbed dose for inorganic chemicals in water

$$DA_{event} = C * Kp * Cw * t_{event}$$ (equation 5c)

Workbook: *MCP GW.xls*, sheet: *DW Dermal*, column M (columns I x L)

parameter		description
DA_{event}	=	absorbed dose per event per area skin exposed (mg/cm^2-event)
FA	=	Fraction absorbed (unitless)
Kp	=	sc permeability constant (cm/hr)
C	=	Conversion Factor (m^3/cm^3)
C_w	=	[OHM] in water (set equal to 1 to yield results per unit concentration) (mg/m^3)
t	=	lag time (time for chemical to cross sc) (hrs)
t_{event}	=	Event duration (hrs)
B	=	Ratio of permeability of chemical in sc to permeability of chemical in ve (dimensionless)

Equation for predicting sc permeability constant (Kp) for organic chemicals:

$$Kp = 10^{\left(-2.8 + 0.67 * \log Kow - 0.0056 * MW\right)}$$ (equation 6)

Workbook: *MCP Toxicity.xls*, sheet: *Toxicity*, column BE

parameter		description
Kp	=	Permeability coefficient (cm/hr)
Kow	=	octanol/water partition coefficient
MW	=	Molecular Weight (g/mole)

Equation for calculating ratio of permeability of chemical in strateum corneum to permeability in viable epidermis (B)

$$B = Kp * \frac{\sqrt{MW}}{2.6}$$ (equation 7)

Workbook: *MCP GW.xls*, sheet: *DW Dermal*, column B

parameter		description
B	=	Ratio of permeability of chemical in strateum corneum to permeability of chemical in viable epidermis (dimensionless)
Kp	=	Permeability coefficient (cm/hr)
MW	=	Molecular Weight (g/mole)

Equations for calculating time to reach steady state (t*)

When B is less than or equal to 0.6:

$t^* = 2.4 * \tau$ (equation 8a)

When B is greater than 0.6:

$$t^* = \left(b - \sqrt{b^2 - c^2} \right) * \frac{l_{sc}^2}{D_{sc}}$$ (equation 8b)

Workbook: *MCP GW.xls*, sheet: *DW Dermal*, column E

parameter		**description**
t*	=	time to reach steady state (hr)
t	=	lag time (time for chemical to cross sc) (hrs)
b	=	empirical variable used to calculate t*
c	=	empirical variable used to calculate t*
l_{sc}	=	thickness of skin (cm)
D_{sc}	=	effective diffusivity for chemical transfer through the skin

Equations for calculating b and c

$$c = \frac{1 + 3B + 3B^2}{3 * (1 + B)}$$ (equation 9)

$$b = \frac{2(1 + B)^2}{\pi} - c$$ (equation 10)

Workbook: *MCP GW.xls*, sheet: *DW Dermal*, columns G and H

parameter		**description**
c	=	empirical variable used to calculate t*
B	=	Ratio of permeability of chemical in sc to permeability of chemical in ve (dimensionless)
b	=	empirical variable used to calculate t*

Equation for calculating lag time (t)

$$\tau = \frac{l_{sc}^{2}}{6 * D_{sc}}$$ (equation 11)

Workbook: *MCP GW.xls*, sheet: *DW Dermal*, column C

parameter		description
l_{sc}	=	thickness of skin (cm)
D_{sc}	=	effective diffusivity for chemical transfer through the skin

Equation for calculating effective diffusivity (D_{sc})

$$D_{sc} = 10^{-2.8-(0.0056 * MW)} * l_{sc}$$ (equation 12)

Workbook: *MCP GW.xls*, sheet: *DW Dermal*, column D

parameter		description
D_{sc}	=	effective diffusivity for chemical transfer through the skin
MW	=	Molecular Weight
l_{sc}	=	thickness of skin (cm)

Inhalation

Inhalation exposures associated with the use of drinking water in the home for showering are evaluated using the approach described in Foster and Chrostowski (1987).

$$[OHM]_{inh-nc} = \frac{HI \times RfC \times C_1}{EXP_{inh-nc}} \quad \text{(equation 13)}$$

Workbook: *MCP GW.xls*, sheet: *GW-1*, column F

parameter		**description**
$[OHM]_{inh-nc}$	=	Target noncancer groundwater concentration based on inhalation (µg/L)
HI	=	Target Hazard Index level (unitless)
RfC	=	inhalation Reference Concentration (mg/m^3)
C_1	=	Conversion Factor (µg/mg)
EXP_{inh-nc}	=	Inhalation Exposure Factor, noncancer ((µg/m^3)/(µg/l))

$$EXP_{inh} = \frac{\frac{S}{R_{ae}} \times \left(D_s + \frac{e^{-R_{ae}D_t}}{R_{ae}} - \frac{e^{R_{ae}(D_s - D_t)}}{R_{ae}} \right) \times n \times EF_1 \times EF_2 \times EP \times C_3}{AP}$$ (equation 14)

Workbook: *MCP GW.xls*, sheet: *DW Inhalation*, column J

parameter		description
EXP_{inh}	=	Inhalation Exposure Factor ((µg/m^3)/(µg/l))
S	=	Indoor air generation rate (µg/(m^3-min))
R_{ae}	=	Air Exchange Rate (1/min)
D_s	=	Shower Duration (minutes)
D_t	=	Total time in shower room (minutes)
n	=	Number of showers per day (unitless)
EF_1	=	Exposure Frequency (days/week)
EF_2	=	Exposure Frequency (weeks/year)
EP		Exposure Period (years)
C_3		Conversion Factor (years/minute)
AP	=	Averaging Period (years)

$$S = \frac{C_{wd} \times FR}{SV}$$ (equation 15)

Workbook: *MCP GW.xls*, sheet: *DW Inhalation*, column I

parameter		description
S	=	Indoor air generation rate (µg/(m^3-min))
C_{wd}	=	Concentration leaving water droplet (µg/l)
FR	=	Shower flow rate (l/minute)
SV	=	Shower room air volume (m^3)

$$C_{wd} = C_{w0}(1 - e^{\frac{-K_{aL} \times t_s}{60d}})$$ (equation 16)

Workbook: *MCP GW.xls*, sheet: *DW Inhalation*, column H

parameter		description
C_{wd}	=	Concentration leaving water droplet (µg/l)
C_{w0}	=	Shower water concentration, set equal to 1 for standard derivation (µg/l)
K_{aL}	=	Adjusted mass transfer coefficient (cm/hr)
t_s	=	Shower droplet time (seconds)
60d	=	the specific interfacial area, 6/d, for a spherical droplet of diameter d (mm), multiplied by conversion factors, hr/3600 sec and 10 mm/cm

$$K_{aL} = K_L \times \sqrt{\frac{T_l \times \mu_s}{T_s \times \mu_l}}$$ (equation 17)

Workbook: *MCP GW.xls*, sheet: *DW Inhalation*, column G

parameter		**description**
K_{aL}	=	Adjusted mass transfer coefficient (cm/hr)
K_L	=	Overall mass transfer coefficient (cm/hr)
T_l	=	Calibration water temperature of K_L (°K)
μ_s	=	Water viscosity at T_s (cp)
T_s	=	Shower water temperature (°K)
μ_l	=	Water viscosity at T_l (cp)

$$K_L = \left(\frac{1}{k_l} + \frac{R \times T}{HLC \times k_g}\right)^{-1}$$ (equation 18)

Workbook: *MCP GW.xls*, sheet: *DW Inhalation*, column F

parameter		**description**
K_L	=	Overall mass transfer coefficient (cm/hr)
k_l	=	Liquid film mass transfer coefficient (cm/hr)
R	=	Universal Gas Constant (atm*m^3/mol* °K)
T	=	Air temperature (°K)
HLC	=	Henry's Law Constant (atm*m^3/mol)
k_g	=	Gas-film mass transfer coefficient (cm/hr)

$$k_l = k_l(CO_2) \times \sqrt{\frac{44}{MW_{voc}}}$$ (equation 19)

Workbook: *MCP GW.xls*, sheet: *DW Inhalation*, column E

parameter		description
k_l	=	Liquid film mass transfer coefficient (cm/hr)
$k_l(CO_2)$	=	Liquid-film mass transfer coefficient, CO_2 (cm/hr)
44	=	Molecular weight of CO_2 (g/mole)
MW_{voc}	=	Molecular Weight of contaminant (g/mole)

$$k_g = k_g(H_2O) \times \sqrt{\frac{18}{MW_{voc}}}$$ (equation 20)

Workbook: *MCP GW.xls*, sheet: *DW Inhalation*, column D

parameter		description
k_g	=	Gas-film mass transfer coefficient (cm/hr)
$k_g(H_2O)$	=	Gas-film mass transfer coefficient, water (cm/hr)
18	=	Molecular weight of water (g/mole)
MW_{voc}	=	Molecular Weight of contaminant (g/mole)

Cumulative Noncancer Risk-Based Concentration

Having calculated the target groundwater concentrations, for ingestion, dermal contact and inhalation separately, a target groundwater concentration protective of all three exposure pathways is calculated using a harmonic mean:

$$[OHM]_{gw-nc} = \frac{1}{\frac{1}{[OHM]_{ing-nc}} + \frac{1}{[OHM]_{dermal-nc}} + \frac{1}{[OHM]_{inh-nc}}} \quad \text{(equation 21)}$$

Workbook: *MCP GW.xls*, sheet: *GW-1*, column G

parameter		**description**
$[OHM]_{gw-nc}$	=	Target noncancer risk-based concentration in groundwater (µg/L)
$[OHM]_{ing-nc}$	=	Target noncancer groundwater concentration based on ingestion (µg/L)
$[OHM]_{dermal-nc}$	=	Target noncancer groundwater concentration based on dermal contact (µg/L)
$[OHM]_{inh-nc}$	=	Target noncancer groundwater concentration based on inhalation (µg/L)

Equations to Calculate Cancer Risk-Based Concentrations

The cancer risk-based concentration of a chemical in drinking water is a function of the ingestion, inhalation, and dermal contact exposures to a hypothetical residential receptor.

Ingestion
The cancer risk-based concentration for the ingestion of drinking water is calculated using the equations:

$$[OHM]_{ing-ca} = \frac{ELCR}{DWEF_{ing-ca} \times RAF_{oral-ca} \times CSF_{oral}}$$ (equation 22)

Workbook*: MCP GW.xls*, sheet: *GW-1, column H*

parameter		**description**
$[OHM]_{ing-ca}$	=	Target cancer risk-based groundwater concentration based on ingestion (µg/L)
ELCR	=	Target Excess Lifetime Cancer Risk (unitless)
$DWEF_{ing-ca}$	=	Drinking Water Exposure Factor for cancer risk, ingestion ((L*mg)/(kg*ug*d))
$RAF_{oral-ca}$	=	Relative Absorption Factor for cancer, oral (unitless)
CSF_{oral}	=	Cancer Slope Factor, oral, $(mg/kg/day)^{-1}$

The exposure term, DWEF ing-ca, is a compilation of receptor exposure assumptions that are not chemical-specific. This factor is calculated:

$$DWEF_{ing-ca} = \frac{VI \times EF_1 \times EF_2 \times EP \times C_1 \times C_2}{BW \times AP}$$ (equation 23)

Workbook*: MCP GW.xls*, sheet: *DW Assumptions*, cell J26

parameter		**description**
$DWEF_{ing-ca}$	=	Drinking Water Exposure Factor for cancer risk, ingestion ((L*mg)/(kg*ug*d))
VI	=	Volume of drinking water ingested (liters/day)
EF_1	=	Exposure Frequency (days/week)
EF_2	=	Exposure Frequency (weeks/year)
EP	=	Exposure Period (years)
C_1	=	Conversion Factor (mg/µg)
C_2	=	Conversion Factor (years/day)
BW	=	Body Weight (kg)
AP	=	Averaging Period (years)

Dermal

The evaluation of dermal exposures associated with the use of drinking water is based on the U.S. EPA's Draft Dermal Exposure Guidance (Equation 24a and subsequent equations in this section). For some chemicals, the estimated results fall outside the "Effective Predictive Domain". For these chemicals, the default approach recommended in the DEP's 1995 *Guidance for Disposal Site Risk Characterization* is used (only Equation 24b).

$$[OHM]_{derm-ca} = \frac{ELCR \times OAE_{ca}}{DWDF_{ca} \times DA_{event} \times CSF}$$ (equation 24a)

$$[OHM]_{derm-ca} = \frac{ELCR \times OAE_{ca}}{DWEF_{ing-ca} \times DM \times CSF}$$ (equation 24b)

Workbook: *MCP GW.xls*, sheet: *GW-1*, column I

parameter		description
$[OHM]_{derm-ca}$	=	Target cancer groundwater concentration based on dermal contact (µg/L)
ELCR	=	Target Excess Lifetime Cancer Risk (unitless)
OAE_{ca}	=	Oral absorption efficiency, cancer
$DWDF_{ca}$	=	Drinking water dermal factor, cancer ((cm^2*event)/(kg*day)). See Equation 4.
CSF	=	Cancer Slope Factor $(mg/kg/day)^{-1}$
$DWEF_{ing-ca}$	=	Drinking water exposure factor, ingestion, cancer ((L*mg)/(kg*ug*d)). See Equation 23.
DM	=	Dermal multiplier (unitless)
DA_{event}	=	Absorbed dose per event, per exposed skin area, per unit concentration ((mg/cm^2-event)/(µg/L)) See Equations 5a, 5b and 5c.

Inhalation
Inhalation exposures associated with the use of drinking water in the home for showering are evaluated using the approach described in Foster and Chrostowski (1987).

$$[OHM]_{inh-ca} = \frac{ELCR}{UR_{air} \times EXP_{inh-ca}} \quad \text{(equation 25)}$$

Workbook: *MCP GW.xls*, sheet: *GW-1*, column J

parameter		description
$[OHM]_{inh-ca}$	=	Target cancer groundwater concentration based on inhalation (µg/L)
ELCR	=	Target Excess Lifetime Cancer Risk (unitless)
EXP_{inh-ca}	=	Inhalation Exposure Factor, cancer ((µg/m^3)/(µg/l)) See Equation 14.

Cumulative Cancer Risk-Based Concentration
Having calculated the target groundwater concentrations, for ingestion, dermal contact and inhalation separately, a target groundwater concentration protective of all three exposure pathways is calculated using a harmonic mean:

$$[OHM]_{gw-ca} = \frac{1}{\frac{1}{[OHM]_{ing-ca}} + \frac{1}{[OHM]_{dermal-ca}} + \frac{1}{[OHM]_{inh-ca}}} \quad \text{(equation 26)}$$

Workbook: *MCP GW.xls*, sheet: *GW-1*, column K

parameter		description
$[OHM]_{ing-ca}$	=	Target cancer groundwater concentration based on ingestion (µg/L)
$[OHM]_{dermal-ca}$	=	Target cancer groundwater concentration based on dermal contact (µg/L)
$[OHM]_{inh-ca}$	=	Target cancer groundwater concentration based on inhalation (µg/L)

Input Parameters

The GW-1 standards are based on the assumed long-term use of groundwater for drinking, cooking and bathing.

Factor	Age	Value	Units	Comment
Body Weight (BW)				
	1-8	16.8	Kg	This value is the arithmetic average of the median (50th %-tile) body weights for each year in this age group (females).
	8-15	39.7	Kg	
	15-30	54.2	Kg	
Drinking Water Intake (VI)				
	1-8	1	Liters/day	Standard USEPA default assumptions, between the mean and 90 th percentile values (EPA, 1997)
	8-30	2	Liters/day	
Showers per day (n)				
	1-30	1	unitless	
Shower Duration (D_s)				
	1-8	45.7	minutes	95 th percentile value (EPA, 1997)
	8-15	42.1	minutes	
	15-30	32.8	minutes	
Time in Shower Room (D_t)				
	1-8	65.7	minutes	D_s + Time spent in room after shower,
	8-15	66.4	minutes	95th percentile value (EPA, 1997)
	15-30	62.8	minutes	
Skin Surface Area (SA)				
	1-8	7130	cm^2	50th percentile value, female, entire body (EPA, 1997)
	8-15	12,800	cm^2	
	15-30	16731	cm^2	
Duration of Dermal Contact with Water (t_{event})				
	1-8	0.76	Hours	Same as D_s, expressed as hours
	8-15	0.70	Hours	
	15-30	0.55	Hours	
Exposure Frequency (EF)				

Factor	Age	Value	Units	Comment
Ingestion & Inhalation				Daily use of water for drinking is assumed. 24% of respondents reported taking more than 1 bath/shower per day. (USEPA, 1997, table 15-24)
EF_1	1-30	7	Days/week	
EF_2	1-30	52	Weeks/year	
Dermal Contact				
EF_1	1-30	1	Events/day	
EF_2	1-30	365	Days/year	
Exposure Period (EP)				
Noncancer	1-8	7	Years	30 years is approximately the 90 th percentile value for residence time. (USEPA, 1997)
Cancer	1-30	30	Years	
Averaging Period (AP)				
Noncancer	1-8	7	Years	Equal to EP for noncancer risk, a lifetime for cancer risk.
Cancer	1-30	70	Years	

MCP Numerical Standards: GW-2

The MCP GW-2 groundwater standards (310 CMR 40.0974(2)) apply to groundwater that is considered both shallow and where there is currently a structure built on the land above the groundwater. These standards are intended to address the potential migration of volatile oil or hazardous material from groundwater into the indoor air.

Documentation for the MCP GW-2 Standards

MCP Category GW-2 Standards (310 CMR 40.0974(2)) apply to groundwater that is considered a potential source of indoor air contamination. These standards apply to groundwater that is both shallow and below an occupied building. The specific regulatory criteria used to determine the applicability of the GW-2 standards are described at 310 CMR 40.0932(6).

The volatilization of oil or hazardous material from contaminated groundwater and its infiltration to indoor air has proven to be a significant exposure pathway at some c.21E sites. Historically the transport of radon gas into indoor air has received a great deal of attention, but it is only recently that this migration pathway has been examined for common volatile organic contaminants. Journal articles (Johnson and Ettinger, 1991; Little et al., 1992) provide discussions of this pathway and develop predictive models for its assessment. Numerous regulatory support documents (USEPA, CTDEP, MIDEP, CO DEP) discuss the use of vapor transport models to evaluate specific environmental conditions.

The model used to develop the MCP GW-2 standards calculates a unique attenuation factor (Î±, or "alpha") for each chemical, assuming highly permeable soil with low moisture content. The attenuation factor relates the indoor air concentration (C_i) to the soil-gas concentration at the surface of the groundwater (C_{sg}): Î±= C_i/C_{sg}.

General Methodology

The GW-2 standards are developed using a variation of the USEPA spreadsheets for the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings to determine the attenuation factor (Î±). The attenuation factor is used in combination with MADEP indoor air risk assessment equations to generate target groundwater concentrations, as described below.

The sequential approach taken to develop the MCP GW-2 standards is as follows:

1. Standard toxicity information, risk assessment methodologies and odor thresholds (when available) are used to identify concentrations in indoor air associated with:

   20% of an allowable intake based on non-cancer health effects (Workbook: *MCP GW.xls*, sheet: *GW-2*, column: B)

   an excess lifetime cancer risk equal to one-in-one million (10^{-6}) (Workbook: *MCP GW.xls*, sheet: *GW-2*, column: C), and

   a 50% odor recognition threshold (Workbook: *MCP GW.xls*, sheet: *GW-2*, column: F).

2. The **lowest** of these three values is carried through the process.

3. A background concentration in indoor air is identified, if available (Workbook: *MCP Toxicity.xls*,

sheet: Toxicity, column: AE).

4. The **higher** of the values identified in steps 2 and 3 is carried through the process.

5. A vapor transport model is used to estimate a concentration in groundwater that would result in the target indoor air concentration identified in step 4.

6. A ceiling concentration of 0.005% (50,000 µg/L) is noted (Workbook: *MCP Toxicity.xls*, sheet: *Toxicity*, column: BP).

7. The **lower** of the concentrations identified in steps 5 and 6 is carried through the process.

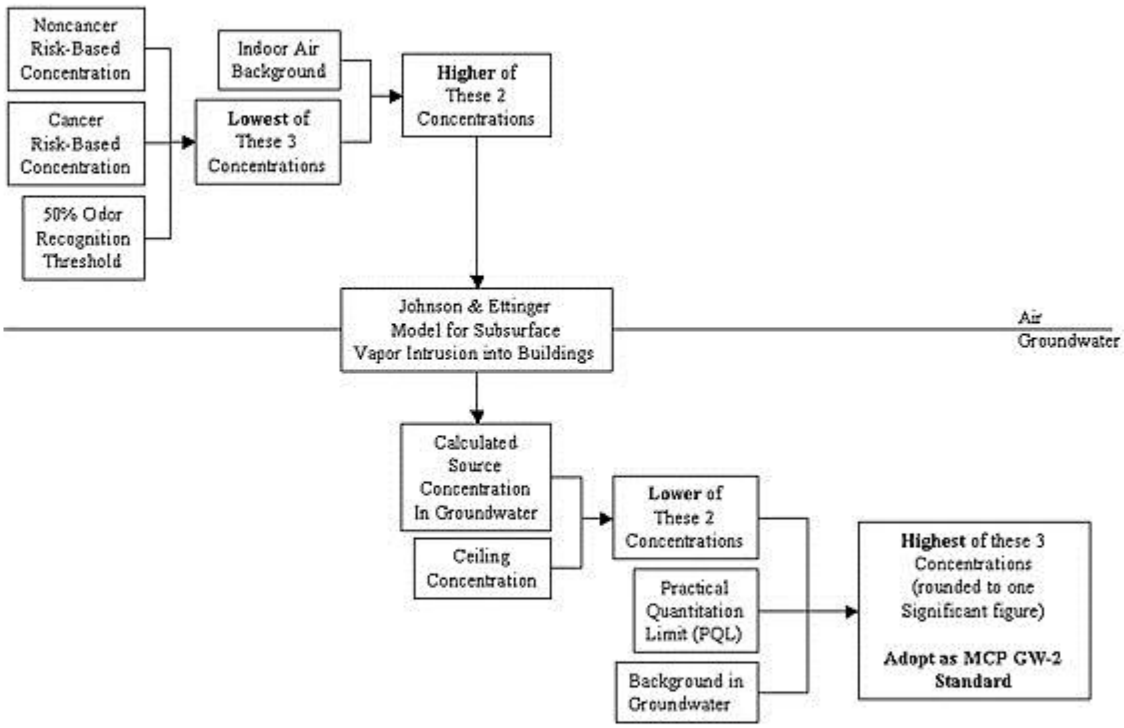
8. A Practical Quantitation Limit (PQL) for an appropriately sensitive analytical method is identified (Workbook: *MCP Toxicity.xls*, sheet: Toxicity, column: AO).

9. A background concentration in groundwater is identified, if available (Workbook: *MCP Toxicity.xls*, sheet: Toxicity, column: AD).

10. The **highest** of the three values identified in steps 7, 8 and 9 is chosen.

11. The value identified in step 10 is rounded to one significant figure. This value is adopted as the MCP GW-2 standard.

This process is diagramed:



Equations

Indoor Air Target Level - Noncancer

$$[OHM]_{air-nc} = RfC \times HI \times IF_{ia-nc} \times C_1$$

Workbook: *MCP GW.xls*, sheet: *GW-2*, column B

Parameter Description

$[OHM]_{air-nc}$ = Indoor air target concentration, noncancer (µg/m3)

RfC = Reference Concentration (µg/m^3)

HI = Target Hazard Index (unitless)

IF_{ia-nc} = Inhalation Factor, noncancer, indoor air

C_1 = Conversion Factor (µg/mg)

$$IF_{ia} = \frac{AP \times C_2}{EF \times EP}$$

Workbook: *MCP GW.xls*, sheet: *GW-2 Exposure*, cell G18 for noncancer, cell G26 for cancer

Parameter **Description**

IFia = Inhalation Factor, indoor air (µg/mg)

AP = Averaging Period (years)

C2 = Conversion Factor (days/year)

EF = Exposure Frequency (days/year)

EP = Exposure period (years)

Indoor Air Target Level - Cancer

$$[OHM]_{air-ca} = \frac{ELCR}{URair} \times IF_{ia-ca}$$

Workbook: *MCP GW.xls*, sheet: *GW-2*, column C

Parameter **Description**

[OHM]air-ca = Indoor air target concentration, cancer (µg/m3)

ELCR = Target Excess Lifetime Cancer Risk (unitless)

URair = Unit Risk, air (µg/m3)-1

IFia-ca = Inhalation Factor, cancer, indoor air
(See Equation above.)

Target Groundwater Value

$$[OHM]_{target-gw} = \frac{[OHM]_{target-air} \times d}{\alpha \times HLC_0 \times C}$$

Workbook: MCP GW.xls, sheet: GW-2, column P

Parameter **Description**

[OHM]target-gw = Target concentration in groundwater (µg/L)

[OHM]target-air = Target concentration in indoor air (µg/m3)

d = DEP dilution, degradation factor (dimensionless)

Î± = Attenuation factor "alpha" (dimensionless)

HLC0 = Dimensionless Henry's Law Constant

C = Conversion Constant (L/m3)

Input Parameters

The GW-2 standards are based on the inhalation of indoor air in a residential setting. Similar to drinking water exposures, exposure is assumed to occur daily over the exposure period.

The attenuation factor depends upon a large number of factors, including:

- depth to groundwater
- concentration of the material in groundwater
- partition coefficients
- groundwater flow
- building structure
- building ventilation rate

The MCP GW-2 standards were derived using chemical-specific attenuation factors (alpha, or Î±) estimated using for sandy soil (permeability of 9.9E-08 cm^2).

Exposure Assumptions:

Factor	Age	Value	Units	Comment
Exposure Frequency (EF)				
Noncancer	1-8	365	Days/year	Residents are assumed to occupy a home continuously.
Cancer	1-30	365	Days/year	
Exposure Period (EP)				
Noncancer	1-8	7	Years	30 years is approximately the 90 th percentile value for residence time. (USEPA, 1997)
Cancer	1-30	30	Years	
Averaging Period (AP)				
Noncancer	1-8	7	Years	Equal to EP for noncancer risk, a lifetime for cancer risk.
Cancer	1-30	70	Years	

Johnson & Ettinger Model Assumptions:

Parameter, Description		Value	Units
L_F	- Depth below grade to bottom of enclosed space floor	183	cm
L_{WT}	- Depth below grade to water table	213	cm
T_S	- Average soil/groundwater temperature	10	°C
h_A	- Thickness of Soil Stratum A	213	cm
h_B, h_C	- Thickness of Soil Strata B and C	0	cm
p_b^A	- Soil dry bulk density	1.5	g/cm^3
n^A	- Soil total porosity	0.43	unitless
θ_w^A	- Soil water-filled porosity	0.06	cm^3/cm^3
L_{crack}	- Enclosed space floor thickness	15	cm
ΔP	- Soil-bldg. pressure differential	40	g/cm-s^2
L_B	- Enclosed space floor length	961	cm
W_B	- Enclosed space floor width	961	cm
H_B	- Enclosed space floor height	488	cm
w	- Floor-wall seam crack width	0.1	cm
ER	- Indoor air exchange rate	0.45	1/h

MCP Numerical Standards: GW-3

The MCP GW-3 groundwater standards (310 CMR 40.0974(2)) apply to all groundwater in the Commonwealth. These standards are intended to address the adverse ecological effects that could result from discharge of oil or hazardous material to surface water.

Documentation for the MCP GW-3 Standards

MCP category GW-3 Standards (310 CMR 40.0974(2))) apply to all groundwater in the Commonwealth, as stipulated in the MCP at 310 CMR 40.0932(2). The GW-3 standards can be regarded as the minimum standards for sites evaluated using MCP Risk Characterization Method 1.

The GW-3 standards are intended to provide some protection against the migration and eventual discharge of groundwater contaminants to surface water at concentrations that could pose a significant risk of harm to aquatic organisms. Risk-based "target values" in surface water are modified by two dilution/attenuation factors to estimate an allowable concentration in groundwater. The two dilution attenuation factors are intended to conservatively account for dilution within the receiving waterbody (Dsw) and attenuation in the groundwater as the contaminant migrates towards the waterbody (Dgw).

General Methodology

The sequential approach taken to develop the MCP GW-3 standards is as follows:

Step Description

1. Risk-based target values in surface water are identified in accordance with an established hierarchy, as described in section 2.3.3.

2. The risk based target value in surface water is multiplied by a dilution/attenuation factor, Dgw to account for dilution between the groundwater and the receiving surface water body

3. The risk-based target value is surface water is multiplied by a dilution/attenuation factor, Dsw to account for dilution of the groundwater in the receiving surface water body.

4. The lower of the concentrations identified in steps 5 and 6 is carried through the process.

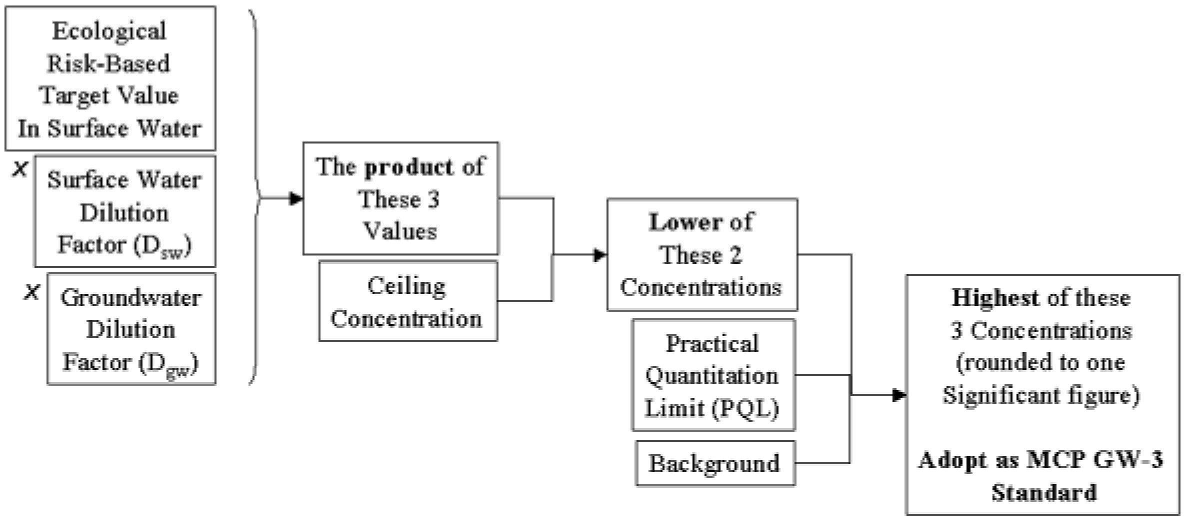
5. A Practical Quantitation Limit (PQL) for an appropriately sensitive analytical method is identified (Workbook: MCP Toxicity.xls, sheet: Toxicity, column: AO).

6. A background concentration in groundwater is identified, if available (Workbook: MCP Toxicity.xls, sheet: Toxicity, column: AD).

7. The highest of the three values identified in steps 7, 8 and 9 is chosen.

8. The value identified in step 10 is rounded to one significant figure. This value is adopted as the MCP GW-3 standard.

This process is diagramed:



Selection of Target Values in Surface Water

The term "target values" refers to the risk-based concentrations on which the GW-3 Standards are based. The target values were chosen in accordance with the following hierarchy:

•If EPA has published National Recommended Water Quality Criteria (NRWQCs), the target value is based on one of the criteria. Preference is given to the lower of the marine and fresh water Criterion Continuous Concentration (CCC, or chronic criterion). If no CCC is available, a Criterion Maximum Concentration (CMC, or acute criterion) is selected.

•If no CCC or CMC is available, the study for which the lowest toxicity value is reported in the AQUIRE database is identified. After reviewing the study to ensure that the results are valid and applicable, the lowest observed effect concentration (LOEC) from the study (if reported) is selected. If a LOEC was not reported, an EC50 (effects concentration for 50% of the test organisms) or LC50 (lethal concentration for 50% of the test organisms) is selected as the basis for the target value.

•If all of the above were unavailable, Suter and Tsao (1996) is reviewed to identify a toxicity study that provides a toxicity concentration suitable for use as the basis for the GW-3 standard.

•If no source of toxicity data is available for the substance in question from the sources identified in the preceding steps, then the references previously selected as sources of toxicity data for other substances were reviewed. If any these contain toxicity information for the substance in question, it is used as a basis for the GW-3 standard for that substance.

•If an acute (for this project, study duration < 7 days) value is selected, the acute concentration is divided by 10 to estimate a chronic value.

For target values selected according to bullets (2) through (4) above, the lowest observed effect concentration (LOEC), or equivalent value from the study is selected if reported in the study. If a LOEC was not reported, an EC50 (effects concentration for 50% of the test organisms) or LC50 (lethal concentration for 50% of the test organisms) is selected as the basis for the target value. The LOEC is given preference over the LC50 because it generally will provide a more accurate estimate of the threshold concentration at which effects can be expected to begin occurring.

The references for the technical studies that are the basis for the surface water benchmark levels are listed in the spreadsheet calculating the GW-3 standards file size1MB (Workbook: MCP GW.xls, sheet SW Target, column AO). A copy of each reference is available for review in each DEP Regional Office and in Boston. Contact Tom Angus (Thomas.Angus@state.ma.us, 617-292-5513) for more information.

Equations

Target Groundwater Level

$$[OHM]_{target-gw} = [OHM]_{eco-sw} \times D_{gw} \times D_{sw}$$

Workbook: MCP GW.xls, sheet: GW-3, column F

parameter description

[OHM]target-gw = Target groundwater concentration (Âµg/L)

[OHM]eco-sw = Identified ecologically-based surface water criterion (Âµg/L)
Workbook: MCP GW.xls, sheet: SW Target, column AC

Dgw = Groundwater-to-surface water dilution factor (dimensionless)
Workbook: MCP GW.xls, sheet: GW-3, column E

Dsw = Dilution factor in the receiving surface water body (dimensionless)
Workbook: MCP GW.xls, sheet: GW-3, column D

Input Parameters

The chemical-specific ecologically-based surface water criteria are listed in spreadsheets (Workbook: MCP GW.xls, sheet: SW Target, column AC) with references provided (Workbook: MCP GW.xls, sheet: SW Target, column AO). Copies of the original literature are available for review, if needed. Please contact Thomas Angus (Thomas.Angus@state.ma.us, 617-292-5513) for more information.

The following table lists the dilutions factors applied in the calculations.

Factor	Value	Units	Comment
D_{sw}	10	dimensionless	
D_{gw}	2.5	dimensionless	$K_{oc} < 10^3$
	25	dimensionless	$10^3 < K_{oc} < 10^6$
	100	dimensionless	$K_{oc} > 10^6$

MCP Numerical Standards: S-1

MCP Numerical Standards have been derived for three categories of soil that were designed to address a broad range of potential human exposures (Categories S-1, S-2 and S-3). The applicability of a particular soil category depends upon both the accessibility of the soil (measured primarily by depth) and the human activities that take place (or may take place) at the surface. Within a soil category there are further sub-categories identified by groundwater type: the soil standards within these subcategories have been modified by the potential for a contaminant to leach and degrade the site groundwater.
The MCP S-1 soil standards (310 CMR 40.0975(6)(a)) apply to soil associated with unrestricted use. Activities commonly associated with the S-1 soil category include residential use, parks, playgrounds and schoolyards. The criteria that define the S-1 soil category are found at 310 CMR 40.0933.

The S-1 soil standards consider incidental ingestion of the soil, dermal contact with the soil and ingestion of produce grown in the soil.

Documentation for the MCP S-1 Standards

The Soil Category S-1 standards are based on a residential exposure scenario in which the potential receptor may come into contact with the contaminated soil in their yard while playing or gardening.

General Methodology

The sequential approach taken to develop the MCP S-1 Soil standards is as follows:

Step Description

1. A noncancer risk-based concentration associated with 20% of an allowable daily intake is identified.

2. A cancer risk-based concentration associated with an excess lifetime cancer risk of one-in-one million (10-6) is identified.

3. A leaching-based concentration (a level in soil considered protective of the applicable groundwater standard) is identified. (Workbook: MCP Leach.xls, Sheet: Leaching, columns: H-J)

4. A ceiling concentration is identified. The ceiling concentration varies by category, as described below. (Workbook: MCP Toxicity.xls, sheet: Toxicity, columns– BS - CA)

5. The lowest of the concentrations identified in steps 1 through 4 is carried through the process.

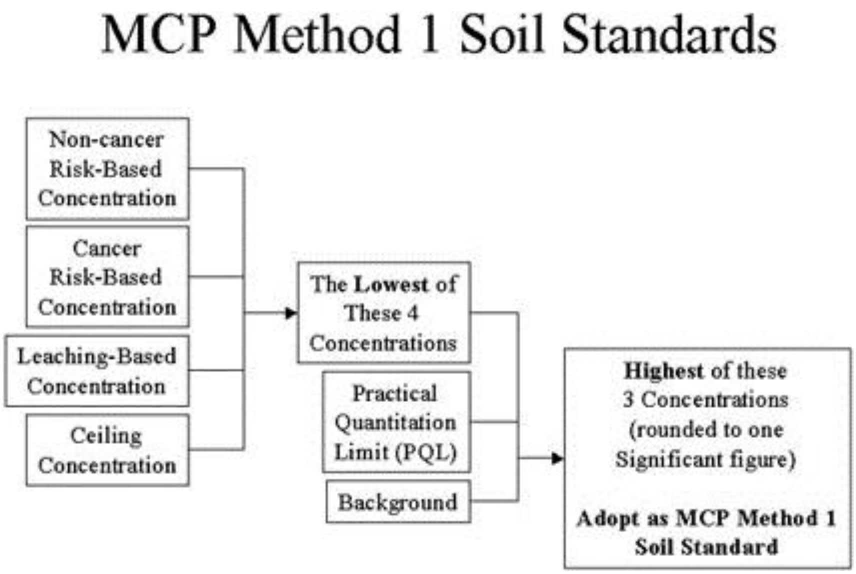
6. A Practical Quantitation Limit (PQL) for an appropriately sensitive analytical method is identified (Workbook: MCP Toxicity.xls, sheet: Toxicity, column:AX).

7. A background concentration is identified, if available (Workbook: MCP Toxicity.xls, sheet: Toxicity, column: AI and AM).

8. The highest of the three values identified in steps 5, 6 and 7 is chosen.

9. The value identified in step 8 is rounded to one significant figure. This value is adopted as the Method 1 Soil Standard for the specified soil category.

This process is diagramed:



Equations

Noncancer Risk-Based Soil Concentrations

The noncancer risk-based concentration of a chemical in soil is a function of the direct contact exposure (ingestion, dermal contact) .

Direct Contact: Ingestion & Dermal Exposures

The noncancer risk-based concentration associated with direct contact with contaminated soil is calculated using the following equation:

$$[OHM]_{nc-dc} = \frac{HI \times RfD_{oral}}{\left(\left(ADSIR \times RAF_{nc-ing}\right) + \left(ADSDCR \times RAF_{nc-dermal}\right)\right)}$$

(equation 1)

Workbook: MCP Soil.xls, Sheet: S-1, column: B

parameter **description**

[OHM]nc-dc = Target noncancer risk-based concentration in soil, based on direct contact (ingestion and dermal exposure) with the soil, (mg/kg)

HI = Target Hazard Index level (unitless)

RfDoral = chronic oral Reference Dose or equivalent toxicity value, (mg/kg/day)

ADSIR = Average Daily Soil Ingestion Rate, (1/day)

RAFnc-ing = Relative Absorption Factor for noncancer, oral exposures (unitless)

ADSDCR = Average Daily Soil Dermal Contact Rate, (1/day)

RAFnc-dermal = Relative Absorption Factor for noncancer, dermal exposures (unitless)

The exposure terms, ADSIR and ADSDCR, are compilations of exposure assumptions that are not chemical-specific. They are calculated as follows.

$$ADSIR = \frac{IR_{soil} \times EF_1 \times EF_2 \times EP}{BW \times AP \times C_1 \times C_2}$$

(equation 2)

Workbook: MCP Soil.xls Sheet: S-1 Assumptions cell: K18

And,

$$ADSDCR = \frac{SSA \times SAF \times EF_1 \times EF_2 \times EP}{BW \times AP \times C_1 \times C_2}$$

(equation 3)

Workbook: MCP Soil.xls Sheet: S-1 Assumptions cell: L43

parameter description

ADSIR = Average Daily Soil Ingestion Rate, (1/day)

IRsoil = Soil Ingestion Rate, (mg/day)

ADSDCR = Average Daily Soil Dermal Contact Rate, (1/day)

SSA = Average Daily Skin Surface Area Exposed, (cm2/day)

SAF = Soil Adherence Factor, (mg/cm2)

EF1 = Exposure Frequency (days/week)

EF2 = Exposure Frequency, (weeks/year)

EP = Exposure Period, (years)

BW = Body Weight (kg)

AP = Averaging Period (years)

C1 = Conversion Factor (365 days/year)

C2 = Conversion Factor (100 mg/kg)

Cancer Risk-Based Soil Concentrations

The cancer risk-based concentration of a chemical in soil is a function of the direct contact exposure (ingestion, dermal contact).

Direct Contact: Ingestion & Dermal Exposures

The cancer risk-based concentration associated with direct contact with contaminated soil is calculated using the following equation:

$$[OHM]_{ca-dc} = \frac{ELCR}{\left(\left(LADSIR \times RAF_{ca-ing}\right) + \left(LADSDCR \times RAF_{ca-dermal}\right)\right) \times CSF_{oral}}$$

(equation 8)

Workbook: MCP Soil.xls, Sheet: S-1, column: C

parameter description

[OHM]ca-dc = Target cancer risk-based concentration in soil, based on direct contact (ingestion and dermal exposure) with the soil, (mg/kg)

ELCR = Target Excess Lifetime Cancer Risk level (unitless)

LADSIR = Lifetime Average Daily Soil Ingestion Rate, (1/day)

RAFca-ing = Relative Absorption Factor for cancer, oral exposures (unitless)

LADSDCR = Lifetime Average Daily Soil Dermal Contact Rate, (1/day)

RAFca-dermal = Relative Absorption Factor for cancer, dermal exposures (unitless)

CSForal = Oral Cancer Slope Factor, (mg/kg/day)-1

The exposure terms, LADSIR and LADSDCR, are compilations of exposure assumptions that are not chemical-specific. Since the cancer risk calculations include exposures that occur over three age groups (1-8 years, 8-15 years, and 15-31 years), the factors are time-weighted averages, as calculated by the following equations:

$$LADSIR = \sum_{x=agegroup1}^{x=agegroup3} \frac{IR_{soil,x} \times EF_{1,x} \times EF_{2,x} \times EP_x}{BW_x \times AP \times C_1 \times C_2}$$

(equation 9)

Workbook: MCP Soil.xls Sheet: S-1 Assumptions cell: K26

And,

$$LADSDCR = \sum_{x=agegroup1}^{x=agegroup3} \frac{SSA_x \times SAF_x \times EF_{1,x} \times EF_{2,x} \times EP_x}{BW_x \times AP \times C_1 \times C_2}$$

(equation 10)

Workbook: MCP Soil.xls Sheet: S-1 Assumptions cell: L51

parameter description

LADSIR = Lifetime Average Daily Soil Ingestion Rate, (1/day)

IRsoil,x = Soil Ingestion Rate, specific to each age group, (mg/day)

LADSDCR = Lifetime Average Daily Soil Dermal Contact Rate, (1/day)

SSAx = Average Daily Skin Surface Area Exposed, specific to each age group (cm2/day)

SAFx = Soil Adherence Factor, specific to each age group (mg/cm2)

EF1,x = Exposure Frequency specific to each age group (days/week)

EF2,x = Exposure Frequency specific to each age group (weeks/year)

EPx = Exposure Period specific to each age group (years)

BWx = Body Weight specific to each age group (kg)

AP = Averaging Period (years)

C1 = Conversion Factor (365 days/year)

C2 = Conversion Factor (106 mg/kg)

Input Parameters

The Method 1 S-1 Soil Standards are based on an assumed residential exposure to soil by children and adults during play and gardening

Factor	**Age**	**Value**	**Units**	**Comment**
Body Weight (BW)				
	1-8	16.8	kg	This value is the arithmetic average of the median (50th %-tile) body weights for each year in this age group (females).
	8-15	39.7	kg	
	15-30	54.2	kg	
Soil Ingestion Rate (IR_{soil})				
	1-8	100	mg/day	MADEP (1995), Appendix B
	8-30	50	mg/day	
Skin Surface Area (SSA)				
	1-8	2,431	cm^2	Average of Median values of the Face, Hands, Forearms, Lower Legs and Feet for each age group. (EPA, 1997)
	8-15	4,427	cm^2	
	15-30	5,653	cm^2	
Soil Adherence Factor (SAF)				
	1-8 8-15 15-30	0.35 0.14 0.13	mg/cm 2	Weighted average of adherence factors for specific body parts exposed (MA DEP 2002)
Exposure Frequency (EF)				
Direct Contact				
EF_1	1-30	5	days/week	
EF_2	1-30	30	weeks/year	
Exposure Period (EP)				
Noncancer	1-8	7	years	30 years is approximately the 90 th percentile value for residence time. (USEPA, 1997)
Cancer	1-30	30	years	
Averaging Period (AP)				
Noncancer	1-8	7	years	Equal to EP for noncancer risk, a lifetime for cancer risk.
Cancer	1-30	70	years	

MCP Numerical Standards: S-2

MCP Numerical Standards have been derived for three categories of soil that were designed to address a broad range of potential human exposures (Categories S-1, S-2 and S-3). The applicability of a particular soil category depends upon both the accessibility of the soil (measured primarily by depth) and the human activities that take place (or may take place) at the surface. Within a soil category there are further sub-categories identified by groundwater type: the soil standards within these subcategories have been modified by the potential for a contaminant to leach and degrade the site groundwater.

The MCP S-2 soil standards (310 CMR 40.0975(6)(b)) apply to soil associated with moderate exposure, including infrequent (or light) use by children. Activities commonly associated with the S-2 soil category include retail use and landscaped areas. The criteria that define the S-2 soil category are found at 310 CMR 40.0933.

The S-2 soil standards consider incidental ingestion of the soil and dermal contact with the soil.

Documentation for the MCP S-2 Standards

The Soil Category S-2 standards are based on an adult exposure scenario in which the potential receptor may come into frequent but passive contact with the contaminated soil.

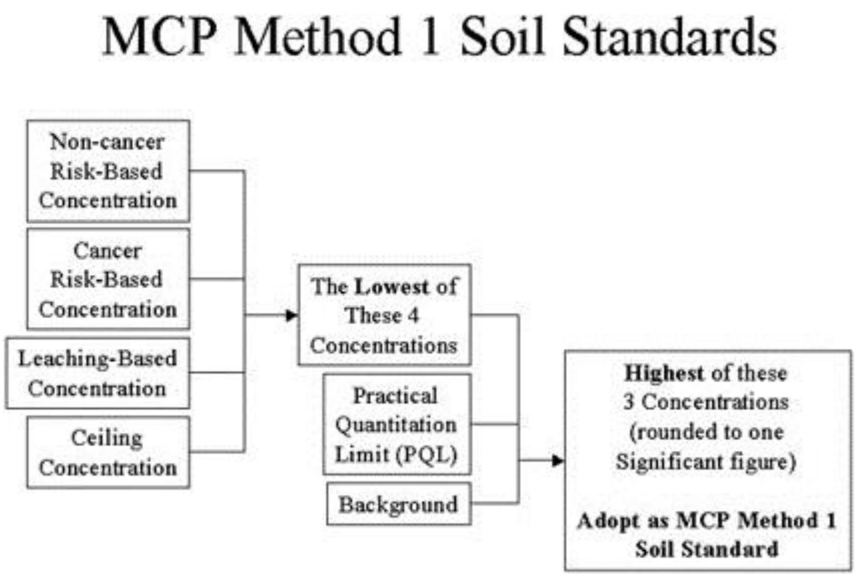
General Methodology

The sequential approach taken to develop the MCP S-2 Soil standards is as follows:

Step Description

1. A noncancer risk-based concentration associated with 20% of an allowable daily intake is identified.
2. A cancer risk-based concentration associated with an excess lifetime cancer risk of one-in-one million (10^{-6}) is identified.
3. A leaching-based concentration (a level in soil considered protective of the applicable groundwater standard) is identified. (Workbook: *MCP Leach.xls*, Sheet: *Leaching*, columns: H-J)
4. A ceiling concentration is identified. The ceiling concentration varies by category, as described below. (Workbook: *MCP Toxicity.xls*, sheet: *Toxicity*, columns BJ - BQ)
5. The **lowest** of the concentrations identified in steps 1 through 4 is carried through the process.
6. A Practical Quantitation Limit (PQL) for an appropriately sensitive analytical method is identified (Workbook: *MCP Toxicity.xls*, sheet: *Toxicity*, column: AP).
7. A background concentration is identified, if available (Workbook: *MCP Toxicity.xls*, sheet: *Toxicity*, column: AD).
8. The **highest** of the three values identified in steps 5, 6 and 7 is chosen.
9. The value identified in step 8 is rounded to one significant figure. This value is adopted as the Method 1 Soil Standard for the specified soil category.

This process is diagramed:



Equations

Noncancer Risk-Based Soil Concentrations

The noncancer risk-based concentration of a chemical in soil is a function of the direct contact exposure (ingestion, dermal contact).

Direct Contact: Ingestion & Dermal Exposures

The noncancer risk-based concentration associated with direct contact with contaminated soil is calculated using the following equation:

$$[OHM]_{nc-dc} = \frac{HI \times RfD_{oral}}{\left(\left(ADSIR \times RAF_{nc-ing}\right) + \left(ADSDCR \times RAF_{nc-dermal}\right)\right)}$$ (equation 1)

Workbook: *MCP Soil.xls*, Sheet: *S-2*, column: B

parameter		**description**
$[OHM]_{nc-dc}$	=	Target noncancer risk-based concentration in soil, based on direct contact (ingestion and dermal exposure) with the soil, (mg/kg)
HI	=	Target Hazard Index level (unitless)
RfD_{oral}	=	chronic oral Reference Dose or equivalent toxicity value, (mg/kg/day)
ADSIR	=	Average Daily Soil Ingestion Rate, (1/day)
RAF_{nc-ing}	=	Relative Absorption Factor for noncancer, oral exposures (unitless)
ADSDCR	=	Average Daily Soil Dermal Contact Rate, (1/day)
$RAF_{nc-dermal}$	=	Relative Absorption Factor for noncancer, dermal exposures (unitless)

The exposure terms, *ADSIR* and *ADSDCR*, are compilations of exposure assumptions that are not chemical-specific. They are calculated as follows.

$$ADSIR = \frac{IR_{soil} \times EF_1 \times EF_2 \times EP}{BW \times AP \times C_1 \times C_2} \quad \text{(equation 2)}$$

Workbook: *MCP Soil.xls* Sheet: *S-2 Assumptions* cell: J21

And,

$$ADSDCR = \frac{SSA \times SAF \times EF_1 \times EF_2 \times EP}{BW \times AP \times C_1 \times C_2} \quad \text{(equation 3)}$$

Workbook: *MCP Soil.xls* Sheet: *S-2 Assumptions* cell: K43

parameter		**description**
ADSIR	=	Average Daily Soil Ingestion Rate, (1/day)
IR_{soil}	=	Soil Ingestion Rate, (mg/day)
ADSDCR	=	Average Daily Soil Dermal Contact Rate, (1/day)
SSA	=	Average Daily Skin Surface Area Exposed, (cm^2/day)
SAF	=	Soil Adherence Factor, (mg/cm^2)
EF_1	=	Exposure Frequency (days/week)
EF_2	=	Exposure Frequency, (weeks/year)
EP	=	Exposure Period, (years)
BW	=	Body Weight (kg)
AP	=	Averaging Period (years)
C_1	=	Conversion Factor (365 days/year)
C_2	=	Conversion Factor (10^6 mg/kg)

Cancer Risk-Based Soil Concentrations

The cancer risk-based concentration of a chemical in soil is a function of the direct contact exposure (ingestion, dermal contact).

Direct Contact: Ingestion & Dermal Exposures

The cancer risk-based concentration associated with direct contact with contaminated soil is calculated using the following equation:

$$[OHM]_{ca-dc} = \frac{ELCR}{((LADSIR \times RAF_{ca-ing}) + (LADSDCR \times RAF_{ca-dermal})) \times CSF_{oral}} \quad \text{(equation 8)}$$

Workbook: *MCP Soil.xls*, Sheet: *S-2*, column: C

parameter		description
$[OHM]_{ca-dc}$	=	Target cancer risk-based concentration in soil, based on direct contact (ingestion and dermal exposure) with the soil, (mg/kg)
ELCR	=	Target Excess Lifetime Cancer Risk level (unitless)
LADSIR	=	Lifetime Average Daily Soil Ingestion Rate, (1/day)
RAF_{ca-ing}	=	Relative Absorption Factor for cancer, oral exposures (unitless)
LADSDCR	=	Lifetime Average Daily Soil Dermal Contact Rate, (1/day)
$RAF_{ca-dermal}$	=	Relative Absorption Factor for cancer, dermal exposures (unitless)
CSF_{oral}	=	Oral Cancer Slope Factor, $(mg/kg/day)^{-1}$

The exposure terms, L*ADSIR* and L*ADSDCR*, are compilations of exposure assumptions that are not chemical-specific. Since the cancer risk calculations include exposures that occur over three age groups (1-8 years, 8-15 years, and 15-31 years), the factors are time-weighted averages, as calculated by the following equations:

$$LADSIR = \sum_{x=agegroup1}^{x=agegroup3} \frac{IR_{soil,x} \times EF_{1,x} \times EF_{2,x} \times EP_x}{BW_x \times AP \times C_1 \times C_2} \quad \text{(equation 9)}$$

Workbook: *MCP Soil.xls* Sheet: *S-2 Assumptions* cell: J29

And,

$$LADSDCR = \sum_{x=agegroup1}^{x=agegroup3} \frac{SSA_x \times SAF_x \times EF_{1,x} \times EF_{2,x} \times EP_x}{BW_x \times AP \times C_1 \times C_2} \quad \text{(equation 10)}$$

Workbook: *MCP Soil.xls* Sheet: *S-2 Assumptions* cell: K51

parameter		description
LADSIR	=	Lifetime Average Daily Soil Ingestion Rate, (1/day)
$IR_{soil,x}$	=	Soil Ingestion Rate, specific to each age group, (mg/day)
LADSDCR	=	Lifetime Average Daily Soil Dermal Contact Rate, (1/day)
SSA_x	=	Average Daily Skin Surface Area Exposed, specific to each age group (cm^2/day)
SAF_x	=	Soil Adherence Factor, specific to each age group (mg/cm^2)
$EF_{1,x}$	=	Exposure Frequency specific to each age group (days/week)
$EF_{2,x}$	=	Exposure Frequency specific to each age group (weeks/year)
EP_x	=	Exposure Period specific to each age group (years)
BW_x	=	Body Weight specific to each age group (kg)
AP	=	Averaging Period (years)
C_1	=	Conversion Factor (365 days/year)
C_2	=	Conversion Factor (10^6 mg/kg)

Input Parameters

The Method 1 S-2 Soil Standards are based on an assumed passive adult exposure to soil.

Factor	Age	Value	Units	Comment
Body Weight (BW)				
	18-45	61.1	kg	This value is the arithmetic average of the median (50th %-tile) body weights for each year in this age group (females).
Soil Ingestion Rate (IR_{soil})				
	18-45	50	mg/day	MADEP (1995), Appendix B
Skin Surface Area (SSA)				
	18-45	3,473	cm^2	Average of median values of the face, hands, forearms, lower legs and feet for adult females. (EPA, 1997)
Soil Adherence Factor (SAF)				
	18-45	0.03	mg/cm^2	Weighted average of adherence factors for specific body parts exposed (MA DEP 2002)
Exposure Frequency (EF)				
EF_1	18-45	4	days/week	EF reflects frequent exposure during warmer months.
EF_2	18-45	30	weeks/year	
Exposure Period (EP)				
	18-45	27	years	Upper percentile value, consistent with long-term employment.
Averaging Period (AP)				
Noncancer	18-45	27	years	Equal to EP for noncancer risk, a lifetime for cancer risk.
Cancer	18-45	70		

MCP Numerical Standards: S-3

MCP Numerical Standards have been derived for three categories of soil that were designed to address a broad range of potential human exposures (Categories S-1, S-2 and S-3). The applicability of a particular soil category depends upon both the accessibility of the soil (measured primarily by depth) and the human activities that take place (or may take place) at the surface. Within a soil category there are further sub-categories identified by groundwater type: the soil standards within these subcategories have been modified by the potential for a contaminant to leach and degrade the site groundwater.

The S-3 soil standards consider incidental ingestion of the soil and dermal contact with the soil.

Documentation for the MCP S-3 Standards

The Soil Category S-3 standards are based on a short but intense construction/excavation exposure scenario in which the potential receptor may come into contact with the contaminated soil through direct contact (ingestion and dermal absorption) and through the inhalation of airborne particulates.

General Methodology

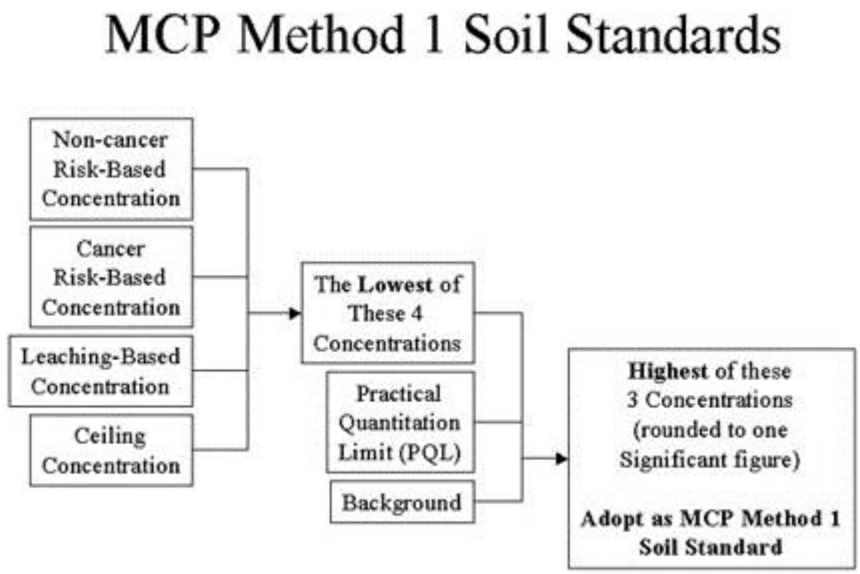
The sequential approach taken to develop the MCP S-3 Soil standards is as follows:

Step	Description
1.	A noncancer risk-based concentration associated with 20% of an allowable daily intake is identified.
2.	A cancer risk-based concentration associated with an excess lifetime cancer risk of one-in-one million (10^{-6}) is identified.
3.	A leaching-based concentration (a level in soil considered protective of the applicable groundwater standard) is identified. (Workbook: *MCP Leach.xls*, Sheet: *Leaching*, columns: H-J)
4.	A ceiling concentration is identified. The ceiling concentration varies by category, as described below. (Workbook: *MCP Toxicity.xls*, sheet: *Toxicity*, columns BJ - BQ)
5.	The **lowest** of the concentrations identified in steps 1 through 4 is carried through the process.
6.	A Practical Quantitation Limit (PQL) for an appropriately sensitive analytical method is identified (Workbook: *MCP Toxicity.xls*, sheet: *Toxicity*, column: AP).
7.	A background concentration is identified, if available (Workbook: *MCP Toxicity.xls*, sheet: *Toxicity*, column: AD).

8. The **highest** of the three values identified in steps 5, 6 and 7 is chosen.

9. The value identified in step 8 is rounded to one significant figure. This value is adopted as the Method 1 Soil Standard for the specified soil category.

This process is diagramed:



Equations

Noncancer Risk-Based Soil Concentrations

The noncancer risk-based concentration of a chemical in soil is a function of the direct contact exposure (ingestion, dermal contact) and inhalation of particulates. Inhalation of particulates can result in both an inhalation exposure (through the lungs), as well as an ingestion exposure when heavier particulates are deposited in the upper respiratory tract and subsequently swallowed (MADEP, 2002).

Ingestion & Dermal Exposures

The noncancer risk-based concentration associated with ingestion and dermal contact with contaminated soil is calculated using the following equation:

$$[OHM]_{nc-id} = \frac{HI \times RfD_{oral}}{\left(\left((ADSIR + ADSIGIE) \times RAF_{nc-ing}\right) + \left(ADSDCR \times RAF_{nc-dermal}\right)\right)}$$ (equation 14)

Workbook: *MCP Soil.xls*, Sheet: *S-3*, column: B

parameter		description
$[OHM]_{nc\text{-}id}$	=	Target noncancer risk-based concentration in soil, based on direct contact (ingestion and dermal exposure) with the soil and ingestion of inhaled particulates, (mg/kg)
HI	=	Target Hazard Index level (unitless)
RfD_{oral}	=	chronic oral Reference Dose or equivalent toxicity value, (mg/kg/day)
ADSIR	=	Average Daily Soil Ingestion Rate, (1/day)
ADSIGIE	=	Average Daily Soil Inhalation - GI Exposure, (1/day)
$RAF_{nc\text{-}ing}$	=	Relative Absorption Factor for noncancer, oral exposures (unitless)
ADSDCR	=	Average Daily Soil Dermal Contact Rate, (1/day)
$RAF_{nc\text{-}dermal}$	=	Relative Absorption Factor for noncancer, dermal exposures (unitless)

The exposure terms, *ADSIR*, *ADSIGIE*, and *ADSDCR*, are compilations of exposure assumptions that are not chemical-specific. They are calculated as follows.

$$ADSIR = \frac{IR_{soil} \times EF_1 \times EF_2 \times EP}{BW \times AP \times C_1 \times C_2} \quad \text{(equation 15)}$$

Workbook: *MCP Soil.xls* Sheet: *S-3 Assumptions* cell: J22

And,

$$ADSIGIE = \frac{PM_{10} \times F_{ing} \times VR_w \times EF_1 \times EF_3 \times EP \times C_4 \times C_8 \times C_9 \times C_{10}}{BW \times AP} \quad \text{(equation 16)}$$

Workbook: *MCP Soil.xls* Sheet: *S-3 Assumptions* cell: O87

And,

$$ADSDCR = \frac{SSA \times SAF \times EF_1 \times EF_2 \times EP}{BW \times AP \times C_1 \times C_2} \quad \text{(equation 17)}$$

Workbook: *MCP Soil.xls* Sheet: *S-3 Assumptions* cell: K44

parameter		description
ADSIR	=	Average Daily Soil Ingestion Rate, (1/day)
ADSIGIE	=	Average Daily Soil Inhalation-GI Exposure, (1/day)
ADSDCR	=	Average Daily Soil Dermal Contact Rate, (1/day)
IR_{soil}	=	Soil Ingestion Rate, (mg/day)
PM_{10}	=	Concentration of Particulate Matter of diameter 10 microns or less in air, ($\mu g/m^3$)
F_{ing}	=	Fraction of PM 10 material ingested, (unitless)
VR_w	=	Ventilation Rate for a worker, (liters/minute)
SSA	=	Average Daily Skin Surface Area Exposed, (cm^2/day)
SAF	=	Soil Adherence Factor, (mg/cm^2)
EF_1	=	Exposure Frequency (days/week)
EF_2	=	Exposure Frequency, (weeks/year)
EF_3	=	Exposure Frequency, (hours/day)
EP	=	Exposure Period, (years)
BW	=	Body Weight (kg)
AP	=	Averaging Period (years)
C_1	=	Conversion Factor (365 days/year)
C_2	=	Conversion Factor (10^6 mg/kg)
C_4	=	Conversion Factor (10^{-9} kg/µg)
C_8	=	Conversion Factor (0.143 weeks/day)
C_9	=	Conversion Factor (0.001 m^3/liter)
C_{10}	=	Conversion Factor (60 minutes/hour)

Inhalation of Airborne Particulates

Typical residential (S-1) exposure scenarios generate little dust from outdoor soil. The risk associated with dust inhalation in a residential setting is insignificant in both an absolute sense and relative to the high direct contact exposures assumed for residents. In contrast, the relative risk from inhalation exposure is higher for a construction/excavation scenario because (a) the activities at the site actively generate dust, increasing the magnitude of this exposure, and (b) the shorter exposure period for construction workers results in a smaller direct contact risk. The noncancer risk-based concentration associated with the inhalation of airborne particulates is calculated using the following equation:

$$[OHM]_{nc-part} = \frac{HI \times RfC_{sub}}{ADSIE} \quad \text{(equation 18)}$$

Workbook: *MCP Soil.xls*, Sheet: *S-3*, column C

parameter		description
$[OHM]_{nc\text{-}part}$	=	Target noncancer risk-based concentration in soil, based on inhalation of airborne particulates, (mg/kg)
HI	=	Target Hazard Index level (unitless)
RfC_{sub}	=	Subchronic inhalation Reference Concentration or equivalent toxicity value, (mg/m^3)
ADSIE	=	Average Daily Soil Inhalation Exposure, (kg/m^3)

The exposure term, *ADSIE*, is a compilation of exposure assumptions that are not chemical-specific. The factor is calculated:

$$ADSIE = \frac{PM_{10} \times F_{inh} \times VR_w \times EF_1 \times EF_3 \times EP \times C_3 \times C_4 \times C_5}{VR_d \times AP}$$
(equation 19)

Workbook: *MCP Soil.xls*, Sheet: *S-3 Assumptions*, cell N66

parameter		description
ADSIE	=	Average Daily Soil Inhalation Exposure, (kg/m^3)
PM_{10}	=	Concentration of Particulate Matter of diameter 10 microns or less in air, (µg/m^3)
F_{inh}	=	Fraction of PM_{10} material inhaled, (unitless)
VR_w	=	Ventilation Rate for a worker, (liters/minute)
VR_d	=	Default Ventilation Rate, (liters/day)
EF_1	=	Exposure Frequency (days/week)
EF_3	=	Exposure Frequency, (hours/day)
EP	=	Exposure Period, (weeks)
AP	=	Averaging Period (weeks)
C_3	=	Conversion Factor (0.006 weeks/hour)
C_4	=	Conversion Factor (10^{-9} kg/µg)
C_5	=	Conversion Factor (1440 minutes/day)

Cumulative Noncancer Risk-Based Soil Concentration

Having calculated the target soil concentrations for indirect contact (ingestion, dermal contact and ingestion of inhaled particulates) and inhalation of particulates separately, a target soil concentration protective of both exposure pathways is calculated using a harmonic mean:

$$[OHM]_{soil-nc} = \frac{1}{\frac{1}{[OHM]_{nc-id}} + \frac{1}{[OHM]_{nc-part}}}$$ (equation 20)

Workbook: *MCP Soil.xls*, sheet: *S-3*, column D

parameter		description
$[OHM]_{soil-nc}$	=	Target noncancer risk-based concentration in soil (mg/kg)
$[OHM]_{nc-id}$	=	Target noncancer concentration in soil based on ingestion and dermal contact (mg/kg)
$[OHM]_{nc-part}$	=	Target noncancer concentration in soil based on inhalation of particulates (mg/kg)

Cancer Risk-Based Soil Concentrations

The cancer risk-based concentration of a chemical in soil is a function of the direct contact exposure (ingestion, dermal contact) and inhalation of particulates. Inhalation of particulates can result in both an inhalation exposure (through the lungs), as well as an ingestion exposure when heavier particulates are deposited in the upper respiratory tract and subsequently swallowed (MADEP, 2002).

Ingestion & Dermal Exposures

The cancer risk-based concentration associated with ingestion and dermal exposure of contaminated soil is calculated using the following equation:

$$[OHM]_{ca-id} = \frac{ELCR}{\left(\left((LADSIR + LADSIGIE) \times RAF_{ca-ing}\right) + \left(LADSDCR \times RAF_{ca-dermal}\right)\right) \times CSF_{oral}}$$ (equation 21)

Workbook: *MCP Soil.xls*, Sheet: *S-3*, column: E

parameter		description
$[OHM]_{ca\text{-}id}$	=	Target cancer risk-based concentration in soil, based on direct contact (ingestion and dermal exposure) with the soil, (mg/kg)
ELCR	=	Target Excess Lifetime Cancer Risk level (unitless)
LADSIR	=	Lifetime Average Daily Soil Ingestion Rate, (1/day)
LADSIGIE	=	Lifetime Average Daily Inhalation-GI Exposure, (1/day)
$RAF_{ca\text{-}ing}$	=	Relative Absorption Factor for cancer, oral exposures (unitless)
LADSDCR	=	Lifetime Average Daily Soil Dermal Contact Rate, (1/day)
$RAF_{ca\text{-}dermal}$	=	Relative Absorption Factor for cancer, dermal exposures (unitless)
CSF_{oral}	=	Oral Cancer Slope Factor, $(mg/kg/day)^{-1}$

The exposure terms, L*ADSIR*, *LADSIGIE* and L*ADSDCR*, are compilations of exposure assumptions that are not chemical-specific. They are calculated as follows.

$$LADSIR = \frac{IR_{soil} \times EF_1 \times EF_2 \times EP}{BW \times AP \times C_{11} \times C_2}$$ (equation 22)

Workbook: *MCP Soil.xls* Sheet: *S-3 Assumptions* cell: J30

And,

$$LADSIGIE = \frac{PM_{10} \times F_{ing} \times VR_w \times EF_1 \times EF_2 \times EF_3 \times EP \times C_4 \times C_9 \times C_{10} \times C_{12}}{BW \times AP}$$ (equation 23)

Workbook: *MCP Soil.xls* Sheet: *S-3 Assumptions* cell: O95

And,

$$LADSDCR = \frac{SSA \times SAF \times EF_1 \times EF_2 \times EP}{BW \times AP \times C_{11} \times C_2}$$ (equation 24)

Workbook: *MCP Soil.xls* Sheet: *S-3 Assumptions* cell: K44

parameter		description
LADSIR	=	Lifetime Average Daily Soil Ingestion Rate, (1/day)
LADSIGIE	=	Lifetime Average Daily Soil Inhalation-GI Exposure, (1/day)
LADSDCR	=	Lifetime Average Daily Soil Dermal Contact Rate, (1/day)
$IR_{soil,x}$	=	Soil Ingestion Rate, specific to each age group, (mg/day)
PM10	=	Concentration of Particulate Matter of diameter 10 microns or less in air, (µg/m3)
Fing	=	Fraction of PM10 material ingested, (unitless)
VR_w	=	Ventilation Rate for a worker, (liters/minute)
SSA_x	=	Average Daily Skin Surface Area Exposed, specific to each age group (cm^2/day)
SAF_x	=	Soil Adherence Factor, specific to each age group (mg/cm^2)
$EF_{1,x}$	=	Exposure Frequency specific to each age group (days/week)
$EF_{2,x}$	=	Exposure Frequency specific to each age group (weeks/year)
EF_3	=	Exposure Frequency, (hours/day)
EP_x	=	Exposure Period specific to each age group (years)
BW_x	=	Body Weight specific to each age group (kg)
AP	=	Averaging Period (years)
C_1	=	Conversion Factor (365 days/year)
C_2	=	Conversion Factor (10^6 mg/kg)
C_4	=	Conversion Factor (10^{-9} kg/µg)
C_9	=	Conversion Factor (0.001 m^3/liter)
C_{10}	=	Conversion Factor (60 minutes/hour)
C_{11}	=	Conversion Factor (365 days/years)
C_{12}	=	Conversion Factor (0.0027 years/day)

Inhalation of Airborne Particulates

As described previously, the relative risk from inhalation exposure is higher for a construction/excavation scenario because (a) the activities at the site actively generate dust, increasing the magnitude of this exposure, and (b) the shorter exposure period for construction workers results in a smaller direct contact risk. The cancer risk-based concentration associated with the inhalation of airborne particulates is calculated using the following equation:

$$[OHM]_{ca-part} = \frac{ELCR}{LADSIE \times UR_{inh}} \quad \text{(equation 25)}$$

Workbook: *MCP Soil.xls*, Sheet: *S-3*, column F

parameter		**description**
$[OHM]_{ca\text{-}part}$	=	Target cancer risk-based concentration in soil, based on inhalation of airborne particulates, (mg/kg)
ELCR	=	Target Excess Lifetime Cancer Risk level (unitless)
UR_{inh}	=	Inhalation Unit Risk value, or equivalent toxicity value, $(\mu g/m^3)^{-1}$
LADSIE	=	Lifetime Average Daily Soil Inhalation Exposure, $((\mu g/m^3)/(mg/kg))$

The exposure term, L*ADSIE*, is a compilation of exposure assumptions that are not chemical-specific. The factor is calculated:

$$LADSIE = \frac{PM_{10} \times F_{inh} \times VR_w \times EF_1 \times EF_2 \times EF_3 \times EP \times C_5 \times C_6 \times C_7}{VR_d \times AP} \quad \text{(equation 26)}$$

Workbook: *MCP Soil.xls*, Sheet: *S-3 Assumptions*, cell N74

parameter		description
LADSIE	=	Lifetime Average Daily Soil Inhalation Exposure, (($\mu g/m^3$)/(mg/kg))
PM_{10}	=	Concentration of Particulate Matter of diameter 10 microns or less in air, ($\mu g/m^3$)
F_{inh}	=	Fraction of PM_{10} material inhaled, (unitless)
VR_w	=	Ventilation Rate for a worker, (liters/minute)
VR_d	=	Default Ventilation Rate, (liters/day)
EF_1	=	Exposure Frequency (days/week)
EF_2	=	Exposure Frequency (weeks/year)
EF_3	=	Exposure Frequency, (hours/day)
EP	=	Exposure Period, (years)
AP	=	Averaging Period (years)
C_5	=	Conversion Factor (1440 minutes/day)
C_6	=	Conversion Factor (1.1E-04 years/hour)
C_7	=	Conversion Factor (10^{-6} kg/mg)

Cumulative Cancer Risk-Based Soil Concentration

Having calculated the target soil concentrations for indirect contact (ingestion, dermal contact and ingestion of inhaled particulates) and inhalation of particulates separately, a target soil concentration protective of both exposure pathways is calculated using a harmonic mean:

$$[OHM]_{soil-ca} = \frac{1}{\frac{1}{[OHM]_{ca-id}} + \frac{1}{[OHM]_{ca-part}}}$$ (equation 27)

Workbook: *MCP Soil.xls*, sheet: *S-3*, column D

parameter		description
$[OHM]_{soil-ca}$	=	Target cancer risk-based concentration in soil (mg/kg)
$[OHM]_{ca-id}$	=	Target cancer concentration in soil based on ingestion and dermal contact (mg/kg)
$[OHM]_{ca-part}$	=	Target cancer concentration in soil based on inhalation of particulates (mg/kg)

Input Parameters

The Method 1 S-3 Soil Standards are based on a short-term adult construction/excavation exposure to soil.

Factor	Age	Value	Units	Comment
Body Weight (BW)				
	22	58	kg	Median (50th %-tile) body weight, ages 18-25 years (females).
Soil Ingestion Rate (IR_{soil})				
	22	100	mg/day	Enhanced soil ingestion rate for construction/excavation workers (MADEP 2002a)
Skin Surface Area (SSA)				
	22	3,473	cm^2	Average of median values of the face, hands, forearms, lower legs and feet for adult females. (EPA, 1997)
Soil Adherence Factor (SAF)				
	22	0.29	mg/cm^2	Weighted average of adherence factors for specific body parts exposed (MA DEP 2002)
Particulate Concentration in Air (PM_{10})				
(PM_{10})	22	60	$\mu g/m^3$	Default PM 10 concentration for excavation scenario (MADEP 1995, Appendix B)
Fraction of Particulates Inhaled (F_{inh})				
(F_{inh})	22	0.5	unitless	Assumed half of the PM 10 material reaches the lung and is available as an inhalation exposure (MADEP, 2002)
Fraction of Particulates Ingested (F_{ing})				
(F_{ing})	22	1.5	unitless	Assumed half of the PM 10 material and all of the PM 10-30 is deposited in the GI tract and is swallowed (MADEP, 2002)
Exposure Frequency (EF)				
EF_1	22	5	days/week	EF reflects an occupational exposure over a 6-month construction project.
EF_2	22	26	weeks/year	
EF_3	22	8	hours/day	
Exposure Period (EP)				
Noncancer	22	26	weeks	Note that for cancer risk, the combination of EF2 and EP calculate to be a 26 week exposure.
Cancer	22	1	year	

Averaging Period (AP)

Noncancer	22	26	weeks	Equal to EP for noncancer risk, a lifetime for cancer risk.
Cancer	22	70	years	

Method 2 Standards

Under the MCP's Method 2 Risk Characterization approach, Method 1 Standards may be supplemented or modified with site- and chemical-specific information. The term "MCP Method 2 Standards" refers both to soil and groundwater standards developed de novo under Method 2 and Method 1 Standards that have been modified under Method 2 to account for site-specific fate-and-transport considerations.

In addition, the MCP provides (310 CMR 40.0982(7)) that the Department may publish optional sets of chemical-specific standards that may be used under Method 2.

MCP Numerical Standards: Method 2

Under the MCP's Method 2 Risk Characterization approach, Method 1 Standards may be supplemented or modified with site- and chemical-specific information. The term "MCP Method 2 Standards" refers both to soil and groundwater standards developed de novo under Method 2 and Method 1 Standards that have been modified under Method 2 to account for site-specific fate-and-transport considerations.

Allowable Method 2 Options:

1. Groundwater and soil standards may be developed, using the approach specified at 310 CMR 40.0983 and 40.0984, for chemicals for which Method 1 Standards have not been promulgated by MADEP.

2. The leaching component of the Method 1 Soil Standards may be modified based on site-specific information, as described at 310 CMR 40.0985. However, any such modification cannot result in Method 2 Standards greater than the Direct Contact Exposure-Based Soil Concentrations listed in Table 5 (310 CMR 40.0985(6)) .

3. The vapor-infiltration component of the Method 1 GW-2 groundwater standards may be modified based on site-specific information, as described at 310 CMR 40.0986. However, any such modification cannot result in Method 2 Standards greater than the Upper Concentration Limits in Groundwater listed in Table 6 (310 CMR 40.0996(7))

4. The groundwater transport and surface water dilution components of the Method 1 GW-3 groundwater standards may be modified based on site-specific information, as described at 310 CMR 40.0987. However, any such modification cannot result in Method 2 Standards greater than the Upper Concentration Limits in Groundwater listed in Table 6 (310 CMR 40.0996(7)) .

5. When developing Method 2 standards for chemicals without promulgated MCP Method 1 standards (#1 above), site-specific fate-and-transport modeling (#'s 2 through 4 above) can be conducted concurrently.

6. Pursuant to 310 CMR 40.0982(7), the Department may make available lists of concentrations in groundwater and soil that can be used under Method 2 to characterize risk for chemicals without promulgated Method 1 Standards. Use of any such MADEP-published values would be an option to developing Method 2 standards de novo.

    - No MADEP-published Method 2 concentrations are available at this time.

Modifications Prohibited Under Method 2:

The Method 1 GW-1 groundwater standards cannot be modified.

The direct-contact component of the Method 1 soil standards cannot be modified.

Upper Concentration Limits (UCLs)

"Upper Concentration Limits" in groundwater and soil are promulgated to minimize potential risks associated with uncontrolled environmental contamination, and the costs associated with cumulative anthropogenic contributions to "background".

The Upper Concentration Limits (UCLs) in Soil and Groundwater (310 CMR 40.0996(7)) are applicable when risk characterization or Method 3 is used to evaluate the potential risk of harm to health, public welfare and the environment. The Upper Concentration Limits (UCLs) are not used in risk characterization Methods 1 as sites meeting the Method 1 Standards meet the Upper Concentration Limits, by definition.

The categorization scheme devised to determine the "current and foreseeable use(s)" of the groundwater and soil (310 CMR 40.0933) describes why the Department is concerned about contamination in these media and related human and/or ecological impacts. Our ability to comprehensively describe (qualitatively or quantitatively) potential impacts is limited, however, particularly impacts which may only become evident in the future. The MCP defines areas of particular interest based upon human and ecological exposure potential and allows some flexibility to establish alternative cleanup requirements using risk assessment in Methods 2 and 3. The Upper Concentration Limits identify contamination which may pose a significant risk of harm to public welfare and the environment in the future, and to minimize the incremental contributions to anthropogenic background. The Department does not endorse the general degradation of groundwater or soil.

The revised MCP contains several features intended to provide protection to all groundwater and soil, including: (a) the requirement to meet the Response Action Performance Standard (RAPS) when characterizing a site (310 CMR 40.0191); (b) the requirement to eliminate all continuing sources of release to the environment (310 CMR 40.1003(5)); and (c) the list of Upper Concentration Limits applicable to all groundwater and soil as public welfare and environmental resource standards (310 CMR 40.0994(3) and 310 CMR 40.0995(5)).

A disposal site may qualify for a Temporary Solution even if the concentrations of oil or hazardous material remaining at the disposal site exceed the Upper Concentration Limits. An exceedance of these standards is interpreted to indicate significant risk of harm to public welfare and/or environmental resources in the future, and thus a Temporary Solution may be appropriate if, for current conditions, a condition of no significant risk of harm to health, safety, public welfare and the environment exists or has been achieved.

The UCLs are simply 10 fold multiples of the highest Method 1 exposure-related (S-1, S-2 or S-3 in soil and GW-1, GW-2 or GW-3 in groundwater) standard, capped at a maximum concentration. For soil, the UCL is capped at 10,000 ug/gram, or 1 %. For groundwater, the UCL is capped at 100,000 ug/L, or 0.01 %.

The Upper Concentration Limits in Soil are listed in Table 6 of the MCP:

Reportable Quantities and Concentrations

Reportable Quantities ("RQs") define notification requirements for sudden releases (or spills) of oil or hazardous materials to the environment.

Reportable Concentrations ("RCs") define notification requirements for contamination discovered in soil and groundwater.

See the online Oil and Hazardous Materials List for RQ and RC values.