5.0 Establishing Reference Ground-water Concentrations

This section presents the RGCs that we used to establish protective constituent concentrations in the modeled well. The constituent-specific MCL and HBN values we used in IWEM are provided in Table 5.4 at the end of this chapter. Appendix E of this background document provides detailed background information on the methodology and human health benchmarks used in developing the HBNs.

The IWEM Tier 1 and Tier 2 evaluations incorporate two types of RGCs:

- ***Maximum Contaminant Levels (MCLs)***. MCLs are available for some constituents in IWEM. MCLs are maximum constituent concentrations allowed in public drinking water and are established under the SDWA. In developing MCLs, EPA considers not only a constituent's health effects, but also additional factors, such as the cost of treatment.

- ***Health-based numbers (HBNs)***. HBNs (for ingestion and/or inhalation route(s) of exposure) are available for all constituents. To calculate HBNs, we only consider parameters that describe a constituent's toxicity and a receptor's exposure to the constituent. For the purposes of developing the Tier 1 and Tier 2 evaluations, HBNs are the maximum constituent concentrations in ground water that we expect generally will not cause adverse noncancer health effects in the general population (including sensitive subgroups), or that will not result in an additional incidence of cancer in more than approximately one in one million individuals exposed to the constituent.

The sections below provide our methodology for calculating the cancer and noncancer HBNs for ingestion and inhalation of the constituents included in the IWEM software. We calculated the HBNs by "rearranging" standard risk equations (see EPA's *Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual* [U.S. EPA, 1991a]) so that we could calculate constituent concentration, rather than cancer risk or noncancer hazard. The standard equations for cancer risk and noncancer hazard are comprised of two sets of variables: variables that describe an individual's exposure to a constituent and a variable that describes the toxicity of the constituent.

Exposure is the condition that occurs when a constituent comes into contact with the outer boundary of the body, such as the mouth and nostrils. Once EPA establishes the concentrations of constituents at the points of exposure, we can estimate the magnitude of each individual's exposure, or the potential dose of constituent. The dose is

the amount of the constituent that crosses the outer boundary of the body and is available for absorption at internal exchange boundaries (lungs, gut, skin) (U.S. EPA, 1992). For example, if an exposure to a carcinogen through ingestion of contaminated drinking water occur, the dose is a function of the concentration of the constituent in drinking water (assumed to be the concentration of the constituent at the receptor well), as well as certain "exposure factors," such as how much drinking water the individual consumes each day (the intake rate), the period of time over which the individual is exposed to the contaminated drinking water (the exposure duration), how often the individual is exposed to contaminated drinking water during the exposure duration (the exposure frequency), and the body weight of the individual. For effects such as cancer, where we usually describe the biological response in terms of lifetime probabilities even though exposure does not occur over the entire lifetime, we average doses over an individual's lifetime, which we call the "averaging time."

Constituent toxicity is described through the use of "human health benchmarks." Human health benchmarks are quantitative expressions of dose-response relationships. Human health benchmarks include:

- Oral cancer slope factors (CSFo) for oral exposure to carcinogenic (cancer-causing) constituents;
- Reference doses (RfD) for oral exposure to constituents that cause noncancer health effects;
- Inhalation cancer slope factors (CSFi), that are derived from Unit Risk Factors (URFs), for inhalation exposure to carcinogenic constituents; and
- Reference concentrations (RfC) for inhalation exposure to constituents that cause noncancer health effects.

EPA defines the cancer slope factor (CSF) as "an upper bound, approximating a 95% confidence limit, on the increased cancer risk from a lifetime exposure to an agent [constituent]." Because the CSF is an upper bound estimate of increased risk, EPA is reasonably confident that the "true risk" will not exceed the risk estimate derived using the CSF and that the "true risk" is likely to be less than predicted. CSFs are expressed in units of proportion (of a population) affected per milligram/kilogram/day (mg/kg/day). For non-cancer health effects, we use the RfD and the RfC as health benchmarks for ingestion and inhalation exposures, respectively. RfDs and RfCs are estimates of daily oral exposure (in the case of an RfD) or a continuous inhalation exposure (in the case of an RfC) that is likely to be without an appreciable risk of adverse effects in the general population, including sensitive individuals, over a lifetime. The methodology used to

develop RfDs and RfCs is expected to have an uncertainty spanning an order of magnitude.

We combined estimates of constituent dose and estimates of constituent toxicity (the health benchmarks) to calculate estimates of excess lifetime cancer risk for individuals who may be exposed to carcinogenic constituents and HQs for those constituents that produce noncancer health effects. Excess lifetime cancer risk is the incremental probability (chance) of an individual developing cancer over a lifetime as a result of exposure to a carcinogen. We estimate cancer risk resulting from exposure to a carcinogenic constituent by multiplying the constituent's CSF by our estimate of constituent dose. We calculate a receptor's ingestion HQ resulting from exposure to a noncarcinogenic constituent by dividing our estimate of daily constituent dose by the RfD (the HQ is the ratio of an individual's chronic daily constituent dose to the RfD for chronic exposures to the constituent). We calculated a receptor's inhalation HQ by dividing the concentration of the constituent in air by the RfC.

We developed the IWEM HBNs to correspond to a "target risk" and a "target HQ." The target risk we use to calculate the HBNs for carcinogens is 1×10^{-6} (one in one million). The target HQ we use to calculate the HBNs for noncarcinogens is 1 (unitless). A HQ of 1 indicates that the estimated dose is equal to the RfD and, therefore, an HQ of 1 is frequently EPA's threshold of concern for noncancer effects. These targets are used to calculate separate HBNs for each constituent of concern, and separate HBNs for each exposure route of concern (ingestion or inhalation). The Tier 1 and Tier 2 evaluations do not consider combined exposure from ground-water ingestion (from drinking water) and ground-water inhalation (from showering), nor do they consider the potential for additive exposure to multiple constituents.

Usually, doses less than the RfD (HQ=1) are not likely to be associated with adverse health effects and, therefore, are less likely to be of regulatory concern. As the frequency and/or magnitude of the exposures exceeding the RfD increase (HQ>1), the probability of adverse effects in a human population increases. However, it should not be categorically concluded that all doses below the RfD are "acceptable" (or will be risk-free) and that all doses in excess of the RfD are "unacceptable" (or will result in adverse effects).

5.1 Ingestion HBNs

Section 5.1.1 describes how we calculated ingestion HBNs for constituents that cause cancer, and Section 5.1.2 describes how we calculated ingestion HBNs for constituents that cause adverse health effects other than cancer.

5.1.1 Ingestion HBNs for Constituents That Cause Cancer

To calculate ingestion HBNs for carcinogens, we rearranged the standard equation for estimating risk so that instead of solving for risk, we solve for constituent concentration in water. The constituent concentration in water that corresponds to the target cancer risk is the cancer HBN for ingestion exposures, as follows:

$$C\_INGEST\_HBN = \frac{Risk\_target \bullet AT \bullet 365}{CSFo \bullet EF \bullet ED \bullet CRw}$$

where

C_INGEST_HBN	=	cancer HBN for ingestion of water (mg/L)
Risk_target	=	target risk for carcinogens = 1×10^{-6}
CSFo	=	constituent -specific oral cancer slope factor $(mg/kg\text{-}d)^{-1}$
AT	=	averaging time = 70 years [yrs]
EF	=	exposure frequency = 350 d/yr
CRw	=	intake rate of water = 0.0252 L/kg/d
ED	=	exposure duration = 30 yr
365	=	conversion factor (d/yr).

In this equation, the CSFo quantifies the toxicity of the constituent. The averaging time, exposure frequency, intake rate of water (which is expressed as the amount of water an individual consumes each day per kilogram of their body weight), and exposure duration quantify aspects of an individual's potential exposure. In our calculation of cancer and noncancer ingestion HBNs, we use data that combine the factors for intake rate and body weight. That is, we express intake in terms of the amount of water an individual consumes per kilogram of their body weight. For example, if an individual consumes 2 liters (L) of water per day (d), and that individual weighs 65 kg, then their intake would be 2 L/d per 65 kg, or 0.03 L/kg/d. Table 5.1 summarizes the basis for the exposure parameter values that we used in this equation.

Inspection of the equation above shows that the HBN value is directly proportional to the target risk. That is, if the target risk were set to 10^{-5} instead of 10^{-6}, we would obtain a 10 times higher HBN value.

Table 5.1 Exposure Parameter Values for Ingestion HBNs – Carcinogens

Exposure Parameter	Value	Units	Source
Drinking Water Intake Rate	25.2	mL/kg/d	The value is a time-weighted average of mean drinking water intake rates (per kilogram body weight) for individuals aged 0 to 29 years. Table 3-7 of the *Exposure Factors Handbook* (U.S. EPA, 1997a)
Exposure Frequency	350	d/yr	The exposure frequency is the number of days per year that an individual is exposed. A value of 350 days per year considers that an individual is away from home for 2 weeks per year. *Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual* (U.S. EPA, 1991a)
Exposure Duration	30	yr	The exposure duration is the number of years that an individual is exposed. Thirty years is the 95th percentile value for population mobility (exposure duration). Table 15-176 of the *Exposure Factors Handbook* (U.S. EPA, 1997b)
Averaging Time	70	yr	Averaging time is the period of time over which a receptor's dose is averaged. When evaluating carcinogens, dose is averaged over the lifetime of the individual, assumed to be 70 years. *Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual* (U.S. EPA, 1991a)

5.1.2 Ingestion HBNs for Constituents that Cause Noncancer Health Effects

To calculate ingestion HBNs for constituents that cause health effects other than cancer, we rearranged the standard equation for estimating HQ so that instead of solving for the HQ, we solve for constituent concentration in water. The constituent concentration in water that corresponds to the target HQ is the cancer HBN for ingestion exposures, as follows:

$$NC\_INGEST\_HBN = \frac{HQ\_target \bullet RfD \bullet 365}{EF \bullet CRw}$$

where

NC_INGEST_HBN	=	noncancer HBN for ingestion of water (mg/L)
HQ_target	=	target HQ for noncarcinogens = 1
RfD	=	constituent-specific reference dose (mg/kg-d)
EF	=	exposure frequency = 350 d/yr
CRw	=	intake rate of water = 0.0426 L/kg/d
365	=	conversion factor (d/yr).

In this equation, the exposure frequency and intake rate of water (expressed as the amount of water an individual consumes each day per kilogram of body weight) quantify aspects of an individual's exposure. To develop noncancer ingestion HBNs that are protective of children, the intake rate in this equation assumes that the individual who is drinking water from the modeled well is a child who is exposed from age 0 to 6 years. Children in this age range typically ingest greater amounts of water per unit body weight (that is, have greater exposure) than do adults.

The RfD in the equation quantifies the toxicity of the constituent. Even though the RfDs that we use in this analysis are defined to pertain to exposures that occur over a lifetime, these "chronic" RfDs commonly are used to evaluate potential noncancer effects associated with exposures that occur over a significant portion of a lifetime (generally assumed to be between seven years and a lifetime). We do not average the dose for noncarcinogens over the lifetime of an individual (the "averaging time") as we do for carcinogens, rather, we average dose over only the period of exposure. Consequently, the values for exposure duration and averaging time are the same, and cancel each other out (that is why they are not included in the above equation). Table 5.2 summarizes the basis for the exposure parameter values that we used in this equation.

Inspection of the equation above shows that the HBN value is directly proportional to the target HQ. That is, if the target risk were set to 0.1 instead of 1, we would obtain a 10 times lower HBN value.

Table 5.2 Exposure Parameter Values for Ingestion HBNs – Noncarcinogens

Exposure Parameter	Value	Units	Source
Drinking Water Intake Rate	42.6	mL/kg/d	The value is a time-weighted average of mean drinking water intake rates (per kilogram body weight) for children aged 0 to 6 years. Table 3-7 of the *Exposure Factors Handbook* (U.S. EPA, 1997a)
Exposure Frequency	350	d/yr	The exposure frequency is the number of days per year that an individual is exposed. A value of 350 days per year considers that an individual is away from home for 2 weeks per year. *Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual* (U.S. EPA, 1991a)

5.2 Inhalation HBNs

In the IWEM tool, the inhalation HBN is the maximum concentration of a constituent in ground water that is not expected to cause adverse health effects in most adults who inhale the constituent as a result of activities associated with showering. We did not evaluate children's shower-related exposure in developing inhalation HBNs because we assume that children take baths. Because we have not yet developed a "bath model" for evaluating children, we do not have inhalation HBNs that consider children's exposure. We calculated inhalation HBNs only for constituents that (1) volatilize (that is, mercury and organic constituents) and (2) have an inhalation health benchmark available (that is, a RfC, inhalation URF, and/or CSFi).

We developed the inhalation HBNs as follows:

First, we used a shower model to calculate, on a per unit ground-water concentration basis, the average concentration of each constituent in indoor air that an adult will be exposed to daily as a result of activities associated with showering. In this analysis, we assume that the shower water is ground water from the well. However, in this step of the analysis we only have to model a "unit" ground-water concentration. This is because the average concentration of a constituent in indoor air is directly proportional to the concentration of the constituent in the water coming into the shower. As a result, we can back-calculate the ground-water concentration that would result in any given constituent concentration in indoor air by simple scaling. Section 5.2.1 describes how we use the shower model to calculate the average concentration of a constituent in indoor air to which an adult is exposed during the day.

Second, we used the unit average constituent concentration in indoor air, determined above, to calculate the HBN. We first calculated the risk or HQ associated with the unit air concentration from the shower model, and then scaled this result to determine the ground-water concentration associated with the target risk level or target HQ. The ground-water concentration that generates the air concentration associated with a risk of 1×10^{-6} or a HQ of 1 is the inhalation HBN.

5.2.1 Calculation of Exposure Concentrations from Showering

Individuals may be exposed to constituents through inhalation of air-phase emissions from ground water. Such exposure may occur during the time spent in the shower while showering, in the shower stall after showering, and in the bathroom after showering. To evaluate these exposures, EPA uses a shower model to estimate constituent concentrations in a shower stall and in bathroom air.

A primary assumption of our evaluation is that constituents are released into household air only as the result of showering activity, and that exposure to air-phase constituents only occurs in the shower stall and in the bathroom. Some investigators evaluate constituent emissions resulting from other household uses of water (for example, use of water in sinks, toilets, washing machines, and dishwashers) and the associated inhalation exposure that occurs during the time spent in the non-bathroom portions of the house (that is, "the remainder of the house"). The model we used only focuses on exposure in the shower stall and bathroom, and the exposure that results from showering. The shower model is based on the mathematical formulation presented in McKone (1987) and Little (1992a). A detailed description of the shower model, its assumptions and limitations, and the parameter values we used to develop inhalation HBNs is provided in Appendix E.

5.2.2 Calculating Inhalation HBNs

To calculate HBNs, we used a unit ground-water concentration (usually 1 mg/L) within the solubility limits of each constituent and implemented the shower model using that concentration. The result of the shower model was the average concentration of a constituent in air to which an individual is exposed on a daily basis. We used this "unit" air concentration to calculate a corresponding "unit" risk (for cancer-causing chemicals) or "unit" HQ (for constituents that cause noncancer health effects). Because ground-water concentration and inhalation risk or hazard are directly proportional, we used simple ratios to adjust the unit ground-water concentration to the ground-water concentration corresponding to the target risk or target HQ (that is, to calculate the inhalation HBNs). Section 5.2.2.1 describes our application of this methodology to carcinogens and Section 5.2.2.2 describes our application of this methodology to noncarcinogens.

5.2.2.1 Inhalation HBNs for Constituents that Cause Cancer

Using the shower model, we estimated the average concentration of a constituent in air to which an individual is exposed on a daily basis. To calculate the inhalation HBN for carcinogens, we first calculate the inhalation risk that corresponds to this modeled constituent concentration:

$$Risk\_modeled = \frac{(Cair\_modeled \bullet IR \bullet ED \bullet EF)}{(BW \bullet AT \bullet 365)} \bullet CSFi$$

where

Risk_modeled	=	inhalation risk resulting from the modeled constituent concentration in air
Cair_modeled	=	average constituent concentration in air to which an individual is exposed during a day (mg/m^3) (calculated from the unit ground-water concentration using the shower model)
IR	=	inhalation rate = 13.25 m^3/d
ED	=	exposure duration = 30 yr
EF	=	exposure frequency = 350 d/yr
BW	=	body weight (kg) = 71.8 kg
AT	=	averaging time = 70 yr
CSFi	=	constituent-specific inhalation cancer slope factor $(mg/kg-d)^{-1}$
365	=	conversion factor (d/yr).

In this equation, the CSFi quantifies the toxicity of the constituent. We use the average constituent concentration in air, inhalation rate, exposure duration, exposure frequency, body weight, and averaging time to quantify the individual's exposure, or dose. Table 5.3 summarizes the basis for the exposure parameter values used in this equation.

Table 5.3 Exposure Parameter Values for Inhalation HBNs

Exposure Parameter	Value	Units	Source
Inhalation Rate	13.25	m^3/d	The value corresponds to the mean inhalation rates for adults (ages 19 to 65+). The value was calculated by averaging the daily mean inhalation rates for females (11.3 m^3/d) and males (15.2 m^3/d). Table 5-23 of the *Exposure Factors Handbook* (U.S. EPA, 1997a)
Body Weight	71.8	kg	The value corresponds to the mean body weight of 18- to 75-year-old men and women. Tables 7-2 and 7-11 of the *Exposure Factors Handbook* (U.S. EPA, 1997a)
Exposure Frequency	350	d/yr	The exposure frequency is the number of days per year that an individual is exposed. A value of 350 days per year considers that an individual is away from home for 2 weeks per year. *Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual* (U.S. EPA, 1991a)
Exposure Duration	30	yr	The exposure duration is the number of years that an individual is exposed. Thirty years is the 95th percentile value for population mobility (exposure duration). Table 15-176 of the *Exposure Factors Handbook* (U.S. EPA, 1997b)
Averaging Time	70	yr	*Risk Assessment Guidance for Superfund: Volume 1—Human Health Evaluation Manual* (U.S. EPA, 1991a)

The modeled constituent concentration in air was based on evaluating a unit constituent concentration in ground water (a constituent concentration in ground water that we selected somewhat arbitrarily). To calculate the ground-water concentration that corresponds to the target inhalation risk (that is, the inhalation HBN) we adjusted the modeled unit ground-water concentration using a simple ratio of target risk and modeled risk:

$$C\_INHALE\_HBN = \frac{Risk\_target}{Risk\_modeled} \bullet C\_GW\_modeled$$

where

C_INHALE_HBN	=	concentration in ground water resulting in target risk (µg/L) (cancer HBN for inhalation)
C_GW_modeled	=	unit concentration in ground water used in shower model (µg/L)
Risk_target	=	target risk for carcinogens = 1×10^{-6}
Risk_modeled	=	risk resulting from ground-water concentration modeled.

This equation assumes that ground-water concentration and inhalation risk are directly proportional, which we confirmed by running the shower model using the target ground-water concentration (the inhalation HBN) for several constituents and comparing the results to the target risk level.

Inspection of the equation above shows that the HBN value is directly proportional to the target risk. That is, if the target risk were set to 10^{-5} instead of 10^{-6}, we would obtain a 10 times higher HBN value.

5.2.2.2 Inhalation HBNs for Constituents that Causes Non-Cancer Health Effects

Calculating inhalation HBNs for noncarcinogens is simpler than calculating HBNs for carcinogens because the toxicity benchmark (RfC) is expressed as a concentration in air. To calculate the HBN, we first determine the HQ resulting from the unit air concentration output by the shower model:

$$HQ\_modeled = \frac{Cair\_modeled}{RfC}$$

where

HQ_modeled	=	HQ resulting from the ground-water concentration modeled (unitless)
Cair_modeled	=	average air concentration to which an individual is exposed during a day (mg/m^3) (calculated from the unit ground-water concentration using the shower model)
RfC	=	constituent-specific reference concentration (mg/m^3).

We then derive the target ground-water concentration (that is, the inhalation HBN) by adjusting the modeled unit ground-water concentration using the ratio of the target HQ to the modeled HQ:

$$NC\_INHALE\_HBN = \frac{HQ\_target}{HQ\_modeled} \bullet C\_GW\_modeled$$

where

NC_INHALE_HBN = concentration in ground water resulting in target HQ (µg/L) (non-cancer HBN for inhalation)
C_GW_modeled = unit concentration in ground water used in shower model (µg/L)
HQ_target = target HQ for noncarcinogens = 1
HQ_modeled = HQ resulting from ground-water concentration modeled.

Inspection of the equation above shows that the HBN value is directly proportional to the target HQ. That is, if the target risk were set to 0.1 instead of 1, we would obtain a 10 times lower HBN value.

Table 5.4 IWEM MCLs and HBNs

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
83-32-9	Acenaphthene			1.5E+00		
75-07-0	Acetaldehyde [Ethanal]				4.1E-02	2.2E-01
67-64-1	Acetone (2-propanone)			2.5E+00		1.5E+03
75-05-8	Acetonitrile (methyl cyanide)					3.1E+00
98-86-2	Acetophenone			2.5E+00		
107-02-8	Acrolein			4.9E-01		3.3E-04
79-06-1	Acrylamide		2.2E-05	4.9E-03	5.1E+00	
79-10-7	Acrylic acid [propenoic acid]			1.2E+01		1.5E+01
107-13-1	Acrylonitrile		1.8E-04	2.5E-02	1.0E-03	3.8E-02
309-00-2	Aldrin		5.7E-06	7.3E-04	1.0E-05	
107-18-6	Allyl alcohol			1.2E-01		
62-53-3	Aniline (benzeneamine)		1.7E-02		2.2E+00	9.3E-01
120-12-7	Anthracene			7.3E+00*		
7440-36-0	Antimony	6.0E-03		9.8E-03		
7440-38-2	Arsenic	5.0E-02	6.4E-05	7.3E-03		
7440-39-3	Barium	2.0E+00		1.7E+00		
56-55-3	Benz{a}anthracene		8.1E-05		1.8E-02*	
71-43-2	Benzene	5.0E-03	1.8E-03		1.6E-03	1.9E-01
92-87-5	Benzidine		4.2E-07	7.3E-02	2.6E+00	
50-32-8	Benzo{a}pyrene	2.0E-04	1.3E-05		5.4E-03*	
205-99-2	Benzo{b}fluoranthene		8.1E-05		6.3E-04	

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
100-44-7	Benzyl chloride		5.7E-04		5.2E-04	
100-51-6	Benzyl alcohol			7.3E+00		
7440-41-7	Beryllium	4.0E-03		4.9E-02		
39638-32-9	Bis(2-chloroisopropyl)ether		1.4E-03	9.8E-01	5.9E-03	
111-44-4	Bis(2-chloroethyl)ether		8.8E-05		1.1E-03	
117-81-7	Bis(2-ethylhexyl)phthalate	6.0E-03	6.9E-03	4.9E-01*	2.8E+01*	1.8E+02*
75-27-4	Bromodichloromethane	8.0E-02	1.6E-03	4.9E-01	8.0E-04	
74-83-9	Bromomethane			3.4E-02		1.5E-02
106-99-0	Butadiene 1,3-				4.0E-05	6.0E-02
71-36-3	Butanol			2.5E+00		
88-85-7	Butyl-4,6-dinitrophenol,2-sec- (Dinoseb)	7.0E-03		2.5E-02		
85-68-7	Butyl benzyl phthalate			4.9E+00*		
7440-43-9	Cadmium	5.0E-03		1.2E-02		
56-23-5	Carbon tetrachloride	5.0E-03	7.4E-04	1.7E-02	7.6E-04	2.1E-02
75-15-0	Carbon disulfide			2.5E+00		1.9E+00
57-74-9	Chlordane	2.0E-03	2.8E-04	1.2E-02	1.5E-03	2.8E-02
126-99-8	Chloro-1,3-butadiene 2-(Chloroprene)			4.9E-01		2.2E-02
106-47-8	Chloroaniline p-			9.8E-02		
108-90-7	Chlorobenzene	1.0E-01		4.9E-01		2.0E-01
510-15-6	Chlorobenzilate		3.6E-04	4.9E-01	1.2E+00	
124-48-1	Chlorodibromomethane	8.0E-02	1.2E-03	4.9E-01	7.5E-04	
75-00-3	Chloroethane [Ethyl chloride]					3.0E+01
67-66-3	Chloroform	8.0E-02		2.5E-01		3.3E-01
74-87-3	Chloromethane		7.4E-03		5.9E-03	2.6E-01
95-57-8	Chlorophenol 2-			1.2E-01		9.7E-03
107-05-1	Chloropropene 3- (Allyl Chloride)				1.9E-03	3.0E-03
16065-83-1	Chromium (III) (Chromic Ion)	1.0E-01		3.7E+01		
18540-29-9	Chromium (VI)	1.0E-01		7.3E-02		
218-01-9	Chrysene		8.1E-04		7.3E-03*	
7440-48-4	Cobalt			4.9E-01		
7440-50-8	Copper	1.3E+00**				
106-44-5	Cresol p-			1.2E-01		1.3E+03

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
108-39-4	Cresol M-			1.2E+00		1.2E+03
95-48-7	Cresol o-			1.2E+00		8.8E+02
1319-77-3	Cresols			1.2E+00		1.1E+03
98-82-8	Cumene			2.5E+00		1.3E+00
108-93-0	Cyclohexanol			4.2E-04		3.9E-04
108-94-1	Cyclohexanone			1.2E+02		
72-54-8	DDD		4.0E-04			
72-55-9	DDE		2.8E-04			
50-29-3	DDT p,p'-		2.8E-04	1.2E-02	8.8E-03	
117-84-0	Di-n-octyl phthalate			4.9E-01*		
84-74-2	Di-n-butyl phthalate			2.5E+00		
2303-16-4	Diallate		1.6E-03			
53-70-3	Dibenz{a,h}anthracene		1.3E-05		3.8E-01	
96-12-8	Dibromo-3-chloropropane 1,2-	2.0E-04	6.9E-05		7.9E-02	2.9E-03
106-46-7	Dichlorobenzene 1,4-	7.5E-02	4.0E-03		1.3E-03	3.0E+00
95-50-1	Dichlorobenzene 1,2-	6.0E-01		2.2E+00		7.7E-01
91-94-1	Dichlorobenzidine 3,3'-		2.2E-04		4.9E+00*	
75-71-8	Dichlorodifluoromethane (Freon 12)			4.9E+00		5.8E-01
107-06-2	Dichloroethane 1,2-	5.0E-03	1.1E-03		6.3E-04	1.0E+01
75-34-3	Dichloroethane 1,1-			2.5E+00	7.4E-03	1.6E+00
156-59-2	Dichloroethylene cis-1,2-	7.0E-02		2.5E-01		
156-60-5	Dichloroethylene trans-1,2-	1.0E-01		4.9E-01		
75-35-4	Dichloroethylene 1,1-	7.0E-03	1.6E-04	2.2E-01	2.2E-04	2.1E-01
120-83-2	Dichlorophenol 2,4-			7.3E-02		
94-75-7	Dichlorophenoxyacetic acid 2,4-(2,4-D)	7.0E-02		2.5E-01		
78-87-5	Dichloropropane 1,2-	5.0E-03	1.4E-03	2.2E+00		1.4E-02
542-75-6	Dichloropropene 1,3-(mixture of isomers)		9.7E-04	7.3E-01	2.9E-03	6.1E-02
10061-02-6	Dichloropropene trans-1,3-		9.7E-04	7.3E-01	3.5E-03	7.5E-02
10061-01-5	Dichloropropene cis-1,3-		9.7E-04	7.3E-01	3.3E-03	7.0E-02
60-57-1	Dieldrin		6.0E-06	1.2E-03	1.0E-04	
84-66-2	Diethyl phthalate			2.0E+01		

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
56-53-1	Diethylstilbestrol		2.1E-08			
60-51-5	Dimethoate			4.9E-03		
119-90-4	Dimethoxybenzidine 3,3'-		6.9E-03			
68-12-2	Dimethyl formamide N,N- [DMF]			2.5E+00		7.1E+02
57-97-6	Dimethylbenz{a}anthracene 7,12-				3.0E-03	
119-93-7	Dimethylbenzidine 3,3'-		1.1E-05			
105-67-9	Dimethylphenol 2,4-			4.9E-01		
99-65-0	Dinitrobenzene 1,3-			2.5E-03		
51-28-5	Dinitrophenol 2,4-			4.9E-02		
121-14-2	Dinitrotoluene 2,4-		1.4E-04	4.9E-02	8.1E-01	
606-20-2	Dinitrotoluene 2,6-		1.4E-04	2.5E-02		
123-91-1	Dioxane 1,4-		8.8E-03		1.8E-01	1.1E+03
122-39-4	Diphenylamine			6.1E-01		
122-66-7	Diphenylhydrazine 1,2-		1.2E-04		2.0E-02	
298-04-4	Disulfoton			9.8E-04		
115-29-7	Endosulfan (Endosulfan I and II, mixture)			1.5E-01		
72-20-8	Endrin	2.0E-03		7.3E-03		
106-89-8	Epichlorohydrin		9.8E-03	4.9E-02	1.9E-01	6.0E-02
106-88-7	Epoxybutane 1,2-					2.4E-01
110-80-5	Ethoxyethanol 2-			9.8E+00		2.9E+03
111-15-9	Ethoxyethanol acetate 2-			7.3E+00		3.0E+02
62-50-0	Ethyl methanesulfonate		3.3E-07			
97-63-2	Ethyl methacrylate			2.2E+00		
141-78-6	Ethyl acetate			2.2E+01		
60-29-7	Ethyl ether			4.9E+00		
100-41-4	Ethylbenzene	7.0E-01		2.5E+00	1.1E-02	3.3E+00
96-45-7	Ethylene thiourea		8.8E-04	2.0E-03	1.6E+03	
107-21-1	Ethylene glycol			4.9E+01		1.2E+04
75-21-8	Ethylene oxide		9.5E-05		5.2E-04	4.1E-01
106-93-4	Ethylene dibromide (1,2-Dibromoethane)	5.0E-05	1.1E-06		8.4E-05	9.8E-04
206-44-0	Fluoranthene			9.8E-01*		

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
16984-48-8	Fluoride	4.0E+00		2.9E+00		
50-00-0	Formaldehyde			4.9e+00	1.5E+00	5.1E+01
64-18-6	Formic acid			4.9E+01		
98-01-1	Furfural			7.3E-02		2.2E+01
319-84-6	HCH alpha-		1.5E-05	2.0E-01	3.6E-04	
58-89-9	HCH (Lindane) gamma-	2.0E-04	7.4E-05	7.3E-03	1.6E-03	
319-85-7	HCH beta-		5.4E-05		1.7E-02	
1024-57-3	Heptachlor epoxide	2.0E-04	1.1E-05	3.2E-04	2.8E-04	
76-44-8	Heptachlor	4.0E-04	2.2E-05	1.2E-02	1.5E-05	
87-68-3	Hexachloro-1,3-butadiene		1.2E-03	7.3E-03	6.1E-04	
118-74-1	Hexachlorobenzene	1.0E-03	6.0E-05	2.0E-02*	3.6E-05	
77-47-4	Hexachlorocyclopentadiene	5.0E-02		1.5E-01		6.9E-04
34465-46-8	Hexachlorodibenzo-p-dioxins [HxCDDs]		6.2E-09		1.4E-07	
55684-94-1	Hexachlorodibenzofurans [HxCDFs]		6.2E-09		1.4E-07	
67-72-1	Hexachloroethane		6.9E-03	2.5E-02	3.3E-03	
70-30-4	Hexachlorophene			7.3E-03		
110-54-3	Hexane N-			2.7E+02*		6.6E-01
7783-06-4	Hydrogen Sulfide			7.3E-02		
193-39-5	Indeno{1,2,3-cd}pyrene		8.1E-05*		3.8E-02*	
78-83-1	Isobutyl alcohol			7.3E+00		
78-59-1	Isophorone		1.0E-01	4.9E+00		5.3E+02
143-50-0	Kepone			1.2E-02		
7439-92-1	Lead	1.5E-02**				
7439-96-5	Manganese			1.2E+00		
7439-97-6	Mercury	2.0E-03		2.5E-03		7.0E-04
126-98-7	Methacrylonitrile			2.5E-03		6.5E-03
67-56-1	Methanol			1.2E+01		1.5E+03
72-43-5	Methoxychlor	4.0E-02		1.2E-01*		
110-49-6	Methoxyethanol acetate 2-			4.9E-02		5.1E+02
109-86-4	Methoxyethanol 2-			2.5E-02		4.4E+02
80-62-6	Methyl methacrylate			3.4E+01		5.3E+00
78-93-3	Methyl ethyl ketone			1.5E+01		3.3E+01

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
298-00-0	Methyl parathion			6.1E-03		
108-10-1	Methyl isobutyl ketone			2.0E+00		1.2E+00
1634-04-4	Methyl tert-butyl ether [MTBE]					1.7E+01
56-49-5	Methylcholanthrene 3-				1.2E-03	
75-09-2	Methylene chloride (Dichloromethane)	5.0E-03	1.3E-02	1.5E+00	2.8E-02	1.0E+01
74-95-3	Methylene bromide (Dibromomethane)			2.5E-01		
7439-98-7	Molybdenum			1.2E-01		
91-20-3	Naphthalene			4.9E-01		1.9E-02
7440-02-0	Nickel			4.9E-01		
98-95-3	Nitrobenzene			1.2E-02		1.5E-01
79-46-9	Nitropropane 2-				2.3E-05	3.3E-01
924-16-3	Nitroso-di-n-butylamine N-		1.8E-05		2.0E-05	
621-64-7	Nitroso-di-n-propylamine N-		1.4E-05		1.5E-03	
55-18-5	Nitrosodiethylamine N-		6.4E-07		4.3E-05	
62-75-9	Nitrosodimethylamine N-		1.9E-06	2.0E-04	4.0E-04	
86-30-6	Nitrosodiphenylamine N-		2.0E-02	4.9E-01	5.2E-01	
10595-95-6	Nitrosomethylethylamine N-		4.4E-06		4.5E-03	
100-75-4	Nitrosopiperidine N-				8.7E-03	
930-55-2	Nitrosopyrrolidine N-		4.6E-05		9.2E-01	
152-16-9	Octamethyl pyrophosphoramide			4.9E-02		
56-38-2	Parathion (ethyl)			1.5E-01		
608-93-5	Pentachlorobenzene			2.0E-02		
36088-22-9	Pentachlorodibenzo-p-dioxins [PeCDDs]		6.2E-10		6.0E-08	
30402-15-4	Pentachlorodibenzofurans [PeCDFs]		1.2E-09		6.3E-08	
82-68-8	Pentachloronitrobenzene (PCNB)		3.7E-04	7.3E-02		
87-86-5	Pentachlorophenol	1.0E-03	8.1E-04	7.3E-01	5.4E+01	
108-95-2	Phenol			1.5E+01		9.0E+02
62-38-4	Phenyl mercuric acetate			2.0E-03		
108-45-2	Phenylenediamine 1,3-			1.5E-01		
298-02-2	Phorate			4.9E-03		
85-44-9	Phthalic anhydride			4.9E+01		1.3E+04*

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
1336-36-3	Polychlorinated biphenyls (Aroclors)	5.0E-04	2.4E-04	4.9E-04	1.4E-04	
23950-58-5	Pronamide			1.8E+00		
75-56-9	Propylene oxide [1,2-Epoxypropane]		4.0E-04		1.7E-02	4.9E-01
129-00-0	Pyrene			7.3E-01*		
110-86-1	Pyridine			2.5E-02		1.4E+00
94-59-7	Safrole		5.4E-04			
7782-49-2	Selenium	5.0E-02		1.2E-01		
7440-22-4	Silver			1.2E-01		
57-24-9	Strychnine and salts			7.3E-03		
100-42-5	Styrene	1.0E-01		4.9E+00		3.6E+00
95-94-3	Tetrachlorobenzene 1,2,4,5-			7.3E-03		
1746-01-6	Tetrachlorodibenzo-p-dioxin 2,3,7,8-	3.0E-08	6.2e-10	2.5E-08	2.2E-09	
51207-31-9	Tetrachlorodibenzofuran 2,3,7,8-		6.2E-09		1.0E-07	
630-20-6	Tetrachloroethane 1,1,1,2-		3.7E-03	7.3E-01	1.9E-03	
79-34-5	Tetrachloroethane 1,1,2,2-		4.8E-04	1.5E+00	5.0E-04	
127-18-4	Tetrachloroethylene	5.0E-03	1.9E-03	2.5E-01	2.1E-02	9.4E-01
58-90-2	Tetrachlorophenol 2,3,4,6-			7.3E-01		
3689-24-5	Tetraethyl dithiopyrophosphate (Sulfotep)			1.2E-02		
7440-28-0	Thallium	2.0E-03		2.0E-03		
137-26-8	Thiram [Thiuram]			1.2E-01		
108-88-3	Toluene	1.0E+00		4.9E+00		1.3E+00
95-80-7	Toluenediamine 2,4-		3.0E-05		7.5E+00	
106-49-0	Toluidine p-		5.1E-04			
95-53-4	Toluidine o-		4.0E-04		3.6E-02	
8001-35-2	Toxaphene (chlorinated camphenes)	3.0E-03	8.8E-05		3.6E-03	
75-25-2	Tribromomethane (Bromoform)	8.0E-02	1.2E-02	4.9E-01	1.9E-02	
76-13-1	Trichloro-1,2,2-trifluoro-ethane 1,1,2-			7.3E+02*		9.5E+01
120-82-1	Trichlorobenzene 1,2,4-	7.0E-02		2.5E-01		8.3E-01
71-55-6	Trichloroethane 1,1,1-	2.0E-01		6.9E+00		6.9E+00
79-00-5	Trichloroethane 1,1,2-	5.0E-03	1.7E-03	9.8E-02	1.1E-03	
79-01-6	Trichloroethylene (Trichloroethylene 1,1,2-)	5.0E-03	8.8E-03		6.8E-03	1.9E+00

Table 5.4 IWEM MCLs and HBNs (continued)

CAS Number	Chemical Name	MCL (mg/L)	Ingestion HBNs		Inhalation HBNs	
			Cancer HBN (mg/L)	Non-Cancer HBN (mg/L)	Cancer HBN (mg/L)	Non-cancer HBN (mg/L)
75-69-4	Trichlorofluoromethane (Freon 11)			7.3E+00		2.1E+00
95-95-4	Trichlorophenol 2,4,5-			2.5E+00		
88-06-2	Trichlorophenol 2,4,6-		8.8E-03		2.8E-01	
93-72-1	Trichlorophenoxy)propionic acid 2-(2,4,5-(Silvex)	5.0E-02		2.0E-01		
93-76-5	Trichlorophenoxyacetic acid 2,4,5-			2.5E-01		
96-18-4	Trichloropropane 1,2,3-		1.4E-05	1.5E-01		3.4E-02
121-44-8	Triethylamine					1.1E-01
99-35-4	Trinitrobenzene (Trinitrobenzene 1,3,5-) sym-			7.3E-01		
126-72-7	Tris(2,3-dibromopropyl)phosphate		9.9E-06			
7440-62-2	Vanadium			1.7E-01		
108-05-4	Vinyl acetate			2.5E+01		1.2E+00
75-01-4	Vinyl chloride	2.0E-03	1.3E-04	7.3E-02	2.5E-03	2.9E-01
95-47-6	Xylene o-			4.9E+01		1.4E+00
108-38-3	Xylene m-			4.9E+01		1.3E+00
106-42-3	Xylene p-			4.9E+01		1.3E+00
1330-20-7	Xylenes (total)	1.0E+01		4.9E+01		1.4E+00
7440-66-6	Zinc			7.3E+00		

Key:
* = Value exceeds constituent's water solubility
** = Value exceeds drinking water action level as specified by 40 CFR 141.32(e)(13) and (14)