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MEMORANDUM
Kansas Department of Health and Environment
Bureau of Environmental Remediation

TO: File

THROUGH: Kurt Limesand, Remedial Section/State Cooperative Unit

FROM: E. Jean Underwood, Remedial Section/State Cooperative Unit

DATE: January 14, 2005

SUBJECT: Proposed Plan for Amendment to the Record of Decision
Pester Burn Pond Superfund Site, Operable Units OU1 and OU2
El Dorado, Kansas

Several "to be considered" (TBC) criteria or guidance were identified during development of the Proposed Plan for Amendment to the Record of Decision (ROD). In order to complete the Administrative Record file for the Site, attached are copies of the following pertinent TBC criteria or guidance as referenced in the Proposed Plan for ROD Amendment. These items are either not readily available to the public or are subject to change and, therefore, are specifically incorporated into the Administrative Record file via this memorandum.

- Kansas Department of Health and Environment, Division of Environment, Bureau of Environmental Remediation: *Risk-Based Standards for Kansas RSK Manual—3rd Version* (March 1, 2003).
- MacDonald, D.D., Ingersoll, C.G., and Berger, T.A.: *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (2000).
- U.S. Environmental Protection Agency, Region 5 RCRA Corrective Action: *Ecological Screening Levels* (August 22, 2003).

Attachments

0753
Site: Pester Refinery
ID # KAD000829846
Break: 5.0
Other: OU1
1-14-05

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ARCHIVES OF Environmental Contamination and Toxicology

Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems

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Abstract. Numerical sediment quality guidelines (SQGs) for freshwater ecosystems have previously been developed using a variety of approaches. Each approach has certain advantages and limitations which influence their application in the sediment quality assessment process. In an effort to focus on the agreement among these various published SQGs, consensus-based SQGs were developed for 28 chemicals of concern in freshwater sediments (*i.e.*, metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and pesticides). For each contaminant of concern, two SQGs were developed from the published SQGs, including a threshold effect concentration (TEC) and a probable effect concentration (PEC). The resultant SQGs for each chemical were evaluated for reliability using matching sediment chemistry and toxicity data from field studies conducted throughout the United States. The results of this evaluation indicated that most of the TECs (*i.e.*, 21 of 28) provide an accurate basis for predicting the absence of sediment toxicity. Similarly, most of the PECs (*i.e.*, 16 of 28) provide an accurate basis for predicting sediment toxicity. Mean PEC quotients were calculated to evaluate the combined effects of multiple contaminants in sediment. Results of the evaluation indicate that the incidence of toxicity is highly correlated to the mean PEC quotient ($R^2 = 0.98$ for 347 samples). It was concluded that the consensus-based SQGs provide a reliable basis for assessing sediment quality conditions in freshwater ecosystems.

Numerical sediment quality guidelines (SQGs; including sediment quality criteria, sediment quality objectives, and sediment quality standards) have been developed by various federal, state, and provincial agencies in North America for both freshwater and marine ecosystems. Such SQGs have been used in numerous applications, including designing monitoring programs, interpreting historical data, evaluating the need for detailed sediment quality assessments, assessing the quality of prospective dredged materials, conducting remedial investigations and ecological risk assessments, and developing sediment quality remediation objectives (Long and MacDonald 1998). Numerical SQGs have also been used by many scientists and managers to identify contaminants of concern in aquatic ecosystems and to rank areas of concern on a regional or national basis (*e.g.*, US EPA 1997a). It is apparent, therefore, that numerical SQGs, when used in combination with other tools, such as sediment toxicity tests, represent a useful approach for assessing the quality of freshwater and marine sediments (MacDonald *et al.* 1992; US EPA 1992, 1996a, 1997a; Adams *et al.* 1992; Ingersoll *et al.* 1996, 1997).

The SQGs that are currently being used in North America have been developed using a variety of approaches. The approaches that have been selected by individual jurisdictions depend on the receptors that are to be considered (*e.g.*, sediment-dwelling organisms, wildlife, or humans), the degree of protection that is to be afforded, the geographic area to which the values are intended to apply (*e.g.*, site-specific, regional, or national), and their intended uses (*e.g.*, screening tools, remediation objectives, identifying toxic and not-toxic samples, bioaccumulation assessment). Guidelines for assessing sediment quality relative to the potential for adverse effects on sediment-dwelling organisms in freshwater systems have been derived using a combination of theoretical and empirical approaches, primarily including the equilibrium partitioning approach (EqPA; Di Toro *et al.* 1991; NYSDEC 1994; US EPA 1997a), screening level concentration approach (SLCA; Persaud *et al.* 1993), effects range approach (ERA; Long and Morgan 1991; Ingersoll *et al.* 1996), effects level approach (ELA; Smith *et al.* 1996; Ingersoll *et al.* 1996), and apparent effects threshold approach (AETA; Cubbage *et al.* 1997). Application of these methods has resulted in the derivation of numerical SQGs for many chemicals of potential concern in freshwater sediments.

Selection of the most appropriate SQGs for specific applications can be a daunting task for sediment assessors. This task is particularly challenging because limited guidance is currently available on the recommended uses of the various SQGs. In addition, the numerical SQGs for any particular substance can differ by several orders of magnitude, depending on the derivation procedure and intended use. The SQG selection process is further complicated due to uncertainties regarding

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the bioavailability of sediment-associated contaminants, the effects of covarying chemicals and chemical mixtures, and the ecological relevance of the guidelines (MacDonald *et al.* 2000). It is not surprising, therefore, that controversies have occurred over the proper use of these sediment quality assessment tools.

This paper represents the third in a series that is intended to address some of the difficulties associated with the assessment of sediment quality conditions using various numerical SQGs. The first paper was focused on resolving the "mixture paradox" that is associated with the application of empirically derived SQGs for individual PAHs. In this case, the paradox was resolved by developing consensus SQGs for ΣPAHs (*i.e.*, total PAHs; Swartz 1999). The second paper was directed at the development and evaluation of consensus-based sediment effect concentrations for total PCBs, which provided a basis for resolving a similar mixture paradox for that group of contaminants using empirically derived SQGs (MacDonald *et al.* 2000). The results of these investigations demonstrated that consensus-based SQGs provide a unifying synthesis of the existing guidelines, reflect causal rather than correlative effects, and account for the effects of contaminant mixtures in sediment (Swartz 1999).

The purpose of this third paper is to further address uncertainties associated with the application of numerical SQGs by providing a unifying synthesis of the published SQGs for freshwater sediments. To this end, the published SQGs for 28 chemical substances were assembled and classified into two categories in accordance with their original narrative intent. These published SQGs were then used to develop two consensus-based SQGs for each contaminant, including a threshold effect concentration (TEC; below which adverse effects are not expected to occur) and a probable effect concentration (PEC; above which adverse effects are expected to occur more often than not). An evaluation of resultant consensus-based SQGs was conducted to provide a basis for determining the ability of these tools to predict the presence, absence, and frequency of sediment toxicity in field-collected sediments from various locations across the United States.

Materials and Methods

Derivation of the Consensus-Based SQGs

A stepwise approach was used to develop the consensus-based SQGs for common contaminants of concern in freshwater sediments. As a first step, the published SQGs that have been derived by various investigators for assessing the quality of freshwater sediments were collated. Next, the SQGs obtained from all sources were evaluated to determine their applicability to this study. To facilitate this evaluation, the supporting documentation for each of the SQGs was reviewed. The collated SQGs were further considered for use in this study if: (1) the methods that were used to derive the SQGs were readily apparent; (2) the SQGs were based on empirical data that related contaminant concentrations to harmful effects on sediment-dwelling organisms or were intended to be predictive of effects on sediment-dwelling organisms (*i.e.*, not simply an indicator of background contamination); and (3) the SQGs had been derived on a *de novo* basis (*i.e.*, not simply adopted from another jurisdiction or source). It was not the intent of this paper to collate bioaccumulation-based SQGs.

The SQGs that were expressed on an organic carbon–normalized basis were converted to dry weight–normalized values at 1% organic carbon (MacDonald *et al.* 1994, 1996; US EPA 1997a). The dry weight–normalized SQGs were utilized because the results of previous studies have shown that they predicted sediment toxicity as well or better than organic carbon–normalized SQGs in field-collected sediments (Barrick *et al.* 1988; Long *et al.* 1995; Ingersoll *et al.* 1996; US EPA 1996a; MacDonald 1997).

The effects-based SQGs that met the selection criteria were then grouped to facilitate the derivation of consensus-based SQGs (Swartz 1999). Specifically, the previously published SQGs for the protection of sediment-dwelling organisms in freshwater ecosystems were grouped into two categories according to their original narrative intent, including TECs and PECs. The TECs were intended to identify contaminant concentrations below which harmful effects on sediment-dwelling organisms were not expected. TECs include threshold effect levels (TELs; Smith *et al.* 1996; US EPA 1996a), effect range low values (ERLs; Long and Morgan 1991), lowest effect levels (LELs; Persaud *et al.* 1993), minimal effect thresholds (METs; EC and MENVIQ 1992), and sediment quality advisory levels (SQALs; US EPA 1997a). The PECs were intended to identify contaminant concentrations above which harmful effects on sediment-dwelling organisms were expected to occur frequently (MacDonald *et al.* 1996; Swartz 1999). PECs include probable effect levels (PELs; Smith *et al.* 1996; US EPA 1996a), effect range median values (ERMs; Long and Morgan 1991); severe effect levels (SELs; Persaud *et al.* 1993), and toxic effect thresholds (TETs; EC and MENVIQ 1992; Table 1).

Following classification of the published SQGs, consensus-based TECs were calculated by determining the geometric mean of the SQGs that were included in this category (Table 2). Likewise, consensus-based PECs were calculated by determining the geometric mean of the PEC-type values (Table 3). The geometric mean, rather than the arithmetic mean or median, was calculated because it provides an estimate of central tendency that is not unduly affected by extreme values and because the distributions of the SQGs were not known (MacDonald *et al.* 2000). Consensus-based TECs or PECs were calculated only if three of more published SQGs were available for a chemical substance or group of substances.

Evaluation of the SQGs

The consensus-based SQGs were critically evaluated to determine if they would provide effective tools for assessing sediment quality conditions in freshwater ecosystems. Specifically, the reliability of the individual or combined consensus-based TECs and PECs for assessing sediment quality conditions was evaluated by determining their predictive ability. In this study, predictive ability is defined as the ability of the various SQGs to correctly classify field-collected sediments as toxic or not toxic, based on the measured concentrations of chemical contaminants. The predictive ability of the SQGs was evaluated using a three-step process.

In the first step of the SQG evaluation process, matching sediment chemistry and biological effects data were compiled for various freshwater locations in the United States. Because the data sets were generated for a wide variety of purposes, each study was evaluated to assure the quality of the data used for evaluating the predictive ability of the SQGs (Long *et al.* 1998; Ingersoll and MacDonald 1999). As a result of this evaluation, data from the following freshwater locations were identified for use in this paper: Grand Calumet River and Indiana Harbor Canal, IN (Hoke *et al.* 1993; Giesy *et al.* 1993; Burton 1994; Dorkin 1994); Indiana Harbor, IN (US EPA 1993a, 1996a, 1996b); Buffalo River, NY (US EPA 1993c, 1996a); Saginaw River, MI (US EPA 1993b, 1996a); Clark Fork River, MT (USFWS 1993); Milltown Reservoir, MT (USFWS 1993); Lower Columbia River, WA (Johnson and Norton 1988); Lower Fox River and Green Bay, WI (Call *et al.* 1991); Potomac River, DC (Schlekat *et al.* 1994; Wade *et al.* 1994; Velinsky *et al.* 1994); Trinity River, TX (Dickson *et al.* 1989; US EPA 1996a); Upper Mississippi River, MN to MO (US EPA 1996a, 1997b);

Table 2. Sediment quality guidelines for metals in freshwater ecosystems that reflect TECs (*i.e.*, below which harmful effects are unlikely to be observed)

	Threshold Effect Concentrations						
Substance	TEL	LEL	MET	ERL	TEL-HA28	SQAL	Consensus-Based TEC
Metals (in mg/kg DW)							
Arsenic	5.9	6	7	33	11	NG	9.79
Cadmium	0.596	0.6	0.9	5	0.58	NG	0.99
Chromium	37.3	26	55	80	36	NG	43.4
Copper	35.7	16	28	70	28	NG	31.6
Lead	35	31	42	35	37	NG	35.8
Mercury	0.174	0.2	0.2	0.15	NG	NG	0.18
Nickel	18	16	35	30	20	NG	22.7
Zinc	123	120	150	120	98	NG	121
Polycyclic aromatic hydrocarbons (in µg/kg DW)							
Anthracene	NG	220	NG	85	10	NG	57.2
Fluorene	NG	190	NG	35	10	540	77.4
Naphthalene	NG	NG	400	340	15	470	176
Phenanthrene	41.9	560	400	225	19	1,800	204
Benz[a]anthracene	31.7	320	400	230	16	NG	108
Benzo(a)pyrene	31.9	370	500	400	32	NG	150
Chrysene	57.1	340	600	400	27	NG	166
Dibenz[a,h]anthracene	NG	60	NG	60	10	NG	33.0
Fluoranthene	111	750	600	600	31	6,200	423
Pyrene	53	490	700	350	44	NG	195
Total PAHs	NG	4,000	NG	4,000	260	NG	1,610
Polychlorinated biphenyls (in µg/kg DW)							
Total PCBs	34.1	70	200	50	32	NG	59.8
Organochlorine pesticides (in µg/kg DW)							
Chlordane	4.5	7	7	0.5	NG	NG	3.24
Dieldrin	2.85	2	2	0.02	NG	110	1.90
Sum DDD	3.54	8	10	2	NG	NG	4.88
Sum DDE	1.42	5	7	2	NG	NG	3.16
Sum DDT	NG	8	9	1	NG	NG	4.16
Total DDTs	7	7	NG	3	NG	NG	5.28
Endrin	2.67	3	8	0.02	NG	42	2.22
Heptachlor epoxide	0.6	5	5	NG	NG	NG	2.47
Lindane (gamma-BHC)	0.94	3	3	NG	NG	3.7	2.37

TEL = Threshold effect level; dry weight (Smith *et al.* 1996)
LEL = Lowest effect level, dry weight (Persaud *et al.* 1993)
MET = Minimal effect threshold; dry weight (EC and MENVIQ 1992)
ERL = Effect range low; dry weight (Long and Morgan 1991)
TEL-HA28 = Threshold effect level for Hyalella azteca; 28 day test; dry weight (US EPA 1996a)
SQAL = Sediment quality advisory levels; dry weight at 1% OC (US EPA 1997a)
NG = No guideline

was evaluated by determining if the sediment sample actually was toxic to one or more aquatic organisms, as indicated by the results of various sediment toxicity tests (Ingersoll and MacDonald 1999). The following responses of aquatic organisms to contaminant challenges (*i.e.*, toxicity test endpoints) were used as indicators of toxicity in this assessment (*i.e.*, sediment samples were designated as toxic if one or more of the following endpoints were significantly different from the responses observed in reference or control sediments), including amphipod (*Hyalella azteca*) survival, growth, or reproduction; mayfly (*Hexagenia limbata*) survival or growth; midge (*Chironomus tentans* or *Chironomus riparius*) survival or growth; midge deformities; oligochaete (*Lumbriculus variegatus*) survival; daphnid (*Ceriodaphnia dubia*) survival; and bacterial (*Photobacterium phosphoreum*) luminescence (*i.e.*, Microtox). In contrast, sediment samples were designated as nontoxic if they did not cause a significant response in at least one of these test endpoints. In this study, predictive ability was calculated as the ratio of the number of samples that were correctly classified as toxic or nontoxic to the total number of samples that were predicted to be toxic or nontoxic using the various SQGs (predictive ability was expressed as a percentage).

The criteria for evaluating the reliability of the consensus-based PECs were adapted from Long *et al.* (1998). These criteria are intended to reflect the narrative intent of each type of SQG (*i.e.*, sediment toxicity should be observed only rarely below the TEC and should be frequently observed above the PEC). Specifically, the individual TECs were considered to provide a reliable basis for assessing the quality of freshwater sediments if more than 75% of the sediment samples were correctly predicted to be not toxic. Similarly, the individual PEC for each substance was considered to be reliable if greater than 75% of the sediment samples were correctly predicted to toxic using the PEC. Therefore, the target levels of both false positives (*i.e.*, samples incorrectly classified as toxic) and false negatives (*i.e.*, samples incorrectly classified as not toxic) was 25% using the TEC and PEC. To assure that the results of the predictive ability evaluation were along with the supporting documentation that was obtained with the published SQGs, was used to evaluate the relevance of the various SQGs in this investigation.

Subsequently, the narrative descriptions of the various SQGs were used to classify the SQGs into appropriate categories (*i.e.*, TECs or PECs; Table 1). The results of this classification process indicated that six sets of SQGs were appropriate for deriving consensus-based TECs for the contaminants of concern in freshwater sediments, including: (1) TELs (Smith *et al.* 1996); (2) LELs (Persaud *et al.* 1993); (3) METs (EC and MENVIQ 1992); (4) ERLs (Long and Morgan 1991); (5) TELs for *H. azteca* in 28-day toxicity tests (US EPA 1996a; Ingersoll *et al.* 1996); and (6) SQALs (US EPA 1997a).

Several other SQGs were also considered for deriving consensus TECs, but they were not included for the following reasons. First, none of the SQGs that have been developed using data on the effects on sediment-associated contaminants in marine sediments only were used to derive TECs. However, the ERLs that were derived using both freshwater and marine data were included (*i.e.*, Long and Morgan 1991). Second, the ERLs that were developed by the US EPA (1996a) were not utilized because they were developed from the same data that were used to derive the TELs (*i.e.*, from several areas of concern in the Great Lakes). In addition, simultaneously extracted metals–acid volatile sulfide (SEM-AVS)–based SQGs were not used because they could not be applied without simultaneous measurements of SEM and AVS concentrations (Di Toro *et al.* 1990). None of the SQGs that were derived using the sediment background approach were used because they were not effects-based. Finally, no bioaccumulation-based SQGs were used to calculate the consensus-based TECs. The published SQGs that corresponded to TECs for metals, PAHs, PCBs, and organochlorine pesticides are presented in Table 2.

Based on the results of the initial evaluation, five sets of SQGs were determined to be appropriate for calculating consensus-based PECs for the contaminants of concern in freshwater sediments, including: (1) probable effect levels (PELs; Smith *et al.* 1996); (2) severe effect levels (SELs; (Persaud *et al.* 1993); (3) toxic effect thresholds (TETs; EC and MENVIQ 1992); (4) effect range median values (ERMs; Long and Morgan 1991); and (5) PELs for *H. azteca* in 28-day toxicity tests (US EPA 1996a; Ingersoll *et al.* 1996).

While several other SQGs were considered for deriving the consensus-based PECs, they were not included for the following reasons. To maximize the applicability of the resultant guidelines to freshwater systems, none of the SQGs that were developed for assessing the quality of marine sediments were used to derive the freshwater PECs. As was the case for the TECs, the ERMs that were derived using both freshwater and marine data (*i.e.*, Long and Morgan 1991) were included, however. The ERMs that were derived using data from various areas of concern in the Great Lakes (*i.e.*, US EPA 1996a) were not included to avoid duplicate representation of these data in the consensus-based PECs. In addition, none of the SEM-AVS–based SQGs were not used in this evaluation. Furthermore, none of the AET or related values (*e.g.*, NECs from Ingersoll *et al.* 1996; PAETs from Cubbage *et al.* 1997) were used because they were not considered to represent toxicity thresholds (rather, they represent contaminant concentrations above which harmful biological effects always occur). The published SQGs that corresponded to PECs for metals, PAHs, PCBs, and organochlorine pesticides are presented in Table 3.

For each substance, consensus-based TECs or PECs were derived if three or more acceptable SQGs were available. The consensus-based TECs or PECs were determined by calculating the geometric mean of the published SQGs and rounding to three significant digits. Application of these procedures facilitated the derivation of numerical SQGs for a total of 28 chemical substances, including 8 trace metals, 10 individual PAHs and PAH classes, total PCBs, and 9 organochlorine pesticides and degradation products. The consensus-based SQGs that were derived for the contaminants of concern in freshwater ecosystems are presented in Tables 2 and 3.

Predictive Ability of the Consensus-Based SQGs

Matching sediment chemistry and toxicity data from various locations in the United States were used to evaluate the predictive ability of the consensus-based SQGs in freshwater sediments. Within this independent data set, the overall incidence of toxicity was about 50% (*i.e.*, 172 of the 347 samples evaluated in these studies were identified as being toxic to one or more sediment-dwelling organisms). Therefore, 50% of the samples with contaminant concentrations below the TEC, between the TEC and the PEC, and above PECs would be predicted to be toxic if sediment toxicity was unrelated to sediment chemistry (*i.e.*, based on random chance alone).

The consensus-based TECs are intended to identify the concentrations of sediment-associated contaminants below which adverse effects on sediment-dwelling organisms are not expected to occur. Sufficient data were available to evaluate the predictive ability of all 28 consensus-based TECs. Based on the results of this assessment, the incidence of sediment toxicity was generally low at contaminant concentrations below the TECs (Table 4). Except for mercury, the predictive ability of the TECs for the trace metals ranged from 72% for chromium to 82% for copper, lead, and zinc. The predictive ability of the TECs for PAHs was similar to that for the trace metals, ranging from 71% to 83%. Among the organochlorine pesticides, the predictive ability of the TECs was highest for chlordane (85%) and lowest for endrin (71%). At 89%, the predictive ability of the TEC for total PCBs was the highest observed among the 28 substances for which SQGs were derived. Overall, the TECs for 21 substances, including four trace metals, eight individual PAHs, total PAHs, total PCBs, and seven organochlorine pesticides, were found to predict accurately the absence of toxicity in freshwater sediments (*i.e.*, predictive ability ≥75%; ≥20 samples below the TEC; Table 4). Therefore, the consensus-based TECs generally provide an accurate basis for predicting the absence of toxicity to sediment-dwelling organisms in freshwater sediments.

In contrast to the TECs, the consensus-based PECs are intended to define the concentrations of sediment-associated contaminants above which adverse effects on sediment-dwelling organisms are likely to be observed. Sufficient data were available to evaluate the PECs for 17 chemical substances, including 7 trace metals, 6 individual PAHs, total PAHs, total PCBs, and 2 organochlorine pesticides (*i.e.*, ≥20 samples predicted to be toxic). The results of the evaluation of predictive ability demonstrate that the PECs for 16 of the 17 substances meet the criteria for predictive ability that

Table 5. Predictive ability of the consensus-based PECs in freshwater sediments

Substance	Number of Samples Evaluated	Number of Samples Predicted to Be Toxic	Number of Samples Observed to Be Toxic	Percentage of Samples Correctly Predicted to Be Toxic
Metals				
Arsenic	150	26	20	76.9
Cadmium	347	126	118	93.7
Chromium	347	109	100	91.7
Copper	347	110	101	91.8
Lead	347	125	112	89.6
Mercury	79	4	4	100
Nickel	347	96	87	90.6
Zinc	347	120	108	90.0
Polycyclic aromatic hydrocarbons				
Anthracene	129	13	13	100
Fluorene	129	13	13	100
Naphthalene	139	26	24	92.3
Phenanthrene	139	25	25	100
Benz(a)anthracene	139	20	20	100
Benzo(a)pyrene	139	24	24	100
Chrysene	139	24	23	95.8
Fluoranthene	139	15	15	100
Pyrene	139	28	27	96.4
Total PAHs	167	20	20	100
Polychlorinated biphenyls				
Total PCBs	120	51	42	82.3
Organochlorine pesticides				
Chlordane	193	37	27	73.0
Dieldrin	180	10	10	100
Sum DDD	168	6	5	83.3
Sum DDE	180	30	29	96.7
Sum DDT	96	12	11	91.7
Total DDT	110	10	10	100
Endrin	170	0	0	NA
Heptachlor epoxide	138	8	3	37.5
Lindane	180	17	14	82.4

NA = Not applicable

step process is used in the present study to calculate mean PEC quotients. In the first step, the concentration of each substance in each sediment sample is divided by its respective consensus-based PEC. PEC quotients are calculated only for those substances for which reliable PECs were available. Subsequently, the sum of the PEC quotients was calculated for each sediment sample by adding the PEC quotients that were determined for each substance; however, only the PECs that were demonstrated to be reliable were used in the calculation. The summed PEC quotients were then normalized to the number of PEC quotients that are calculated for each sediment sample (*i.e.*, to calculate the mean PEC quotient for each sample; Canfield *et al.* 1998; Long *et al.* 1998; Kemble *et al.* 1999). This normalization step is conducted to provide comparable indices of contamination among samples for which different numbers of chemical substances were analyzed.

The predictive ability of the PEC quotients, as calculated using the consensus-based SQGs, was also evaluated using data that were assembled to support the predictive ability assessment for the individual PECs. In this evaluation, sediment samples were predicted to be not toxic if mean PEC quotients were <0.1 or <0.5. In contrast, sediment samples were predicted to be toxic when mean PEC quotients exceeded 0.5, 1.0, or 1.5. The results of this evaluation indicated that the consensus-based SQGs, when used, together provide an accurate basis for predicting the absence of sediment toxicity (Table 7; Figure 1). Sixty-one sediment samples had mean PEC quotients of <0.1; six of these samples were toxic to sediment-dwelling organisms (predictive ability = 90%). Of the 174 samples with mean PEC quotients of < 0.5, only 30 were found to be toxic to sediment-dwelling organisms (predictive ability = 83%; Table 7).

The consensus-based SQGs also provided an accurate basis for predicting sediment toxicity in sediments that contained mixtures of contaminants. Of the 173 sediment samples with mean PEC quotients of > 0.5 (calculated using the PECs for seven trace metals, the PEC for total PAHs [rather than the PECs for individual PAHs], the PEC for PCBs, and the PEC for sum DDE), 147 (85%) were toxic to sediment-dwelling organisms (Table 7; Figure 1). Similarly, 92% of the sediment samples (132 of 143) with mean PEC quotients of > 1.0 were toxic to one or more species of aquatic organisms. Likewise, 94% of the sediment samples (118 of 125) with mean PEC quotients of greater than 1.5 were found to be toxic, based on the results of various freshwater toxicity tests. Therefore, it is apparent that a mean PEC quotient of 0.5 represents a useful equation can be used to estimate the probability of observing sediment toxicity at any mean PEC quotient.

Although it is important to be able to predict accurately the presence and absence of toxicity in field-collected sediments, it is also helpful to be able to identify the factors that are causing or substantially contributing to sediment toxicity. Such information enables environmental managers to focus limited resources on the highest-priority sediment quality issues and concerns. In this context, it has been suggested that the results of spiked sediment toxicity tests provide a basis for identifying the concentrations of sediment-associated contaminants that cause sediment toxicity (Swartz *et al.* 1988; Ingersoll *et al.* 1997). Unfortunately, there is limited relevant data available that assesses effects of spiked sediment in freshwater systems. For example, the available data from spiked sediment toxicity tests is limited to just a few of the chemical substances for which reliable PECs are available, primarily copper and fluoranthene. Additionally, differences in spiking procedures, equilibration time, and lighting conditions during exposures confound the interpretation of the results of sediment spiking studies, especially for PAHs (ASTM 1999). Moreover, many sediment spiking studies were conducted to evaluate bioaccumulation using relatively insensitive test organisms (*e.g.*, *Diporeia* and *Lumbriculus*) or in sediments containing mixtures of chemical substances (Landrum *et al.* 1989, 1991).

In spite of the limitations associated with the available dose-response data, the consensus-based PECs for copper and fluoranthene were compared to the results of spiked sediment toxicity tests. Suedel (1995) conducted a series of sediment spiking studies with copper and reported 48-h to 14-day LC_{50} for four freshwater species, including the waterfleas *Ceriodaphnia dubia* (32–129 mg/kg DW) and *Daphnia magna* (37–170 mg/kg DW), the amphipod *H. azteca* (247–424 mg/kg DW), and the midge *C. tentans* (1,026–4,522 mg/kg DW). An earlier study reported 10-day LC_{50}s of copper for *H. azteca* (1,078 mg/kg) and *C. tentans* (857 mg/kg), with somewhat higher effect concentrations observed in different sediment types (Cairns *et al.* 1984). The PEC for copper (149 mg/kg DW) is higher than or comparable to (*i.e.*, within a factor of three; MacDonald *et al.* 1996; Smith *et al.* 1996) the median lethal concentrations for several of these species. For fluoranthene, Suedel and Rodgers (1993) reported 10-day EC_{50}s of 4.2–15.0 mg/kg, 2.3–7.4 mg/kg, and 3.0–8.7 mg/kg for *D. magna*, *H. azteca*, and *C. tentans*, respectively. The lower of the values reported for each species are comparable to the PEC for fluoranthene that was derived in this study (*i.e.*, 2.23 mg/kg). Much higher toxicity thresholds have been reported in other studies (*e.g.*, Kane Driscoll *et al.* 1997; Kane Driscoll and Landrum 1997), but it is likely that these results were influenced by the lighting conditions under which the tests were conducted. Although this evaluation was made with limited data, the results suggest that the consensus-based SQGs are comparable to the acute toxicity thresholds that have been obtained from spiking studies.

A second approach—to identify concentrations of sediment-associated contaminants that cause or contribute to toxicity—was to compare our consensus-based PECs to equilibrium partitioning values (Swartz 1999; MacDonald *et al.* 1999). The equilibrium partitioning (EqP) approach provides a theoretical basis for deriving sediment quality guidelines for the protection of freshwater organisms (Di Toro *et al.* 1991; Zarba 1992). Using this approach, the US EPA (1997a) developed SQGs that are intended to represent chronic toxicity thresholds for various sediment-associated contaminants, primarily nonionic organic substances. The concentrations of these contaminants are considered to be sufficient to cause or substantially contribute to sediment toxicity when they exceed the EqP-based SQGs (Berry *et al.* 1996). To evaluate the extent to which the consensus-based SQGs are causally based, the PECs were compared to the chronic toxicity thresholds that have been developed previously using the EqP approach (see Table 2). The results of this evaluation indicate that the consensus-based PECs are generally comparable to the EqP-based SQGs (*i.e.*, within a factor of three; MacDonald *et al.* 1996; Smith *et al.* 1996). Therefore, the consensus-based PECs also define concentrations of sediment-associated contaminants that are sufficient to cause or substantially contribute to sediment toxicity.

Summary

Consensus-based SQGs were derived for 28 common chemicals of concern in freshwater sediments. For each chemical substance, two consensus-based SQGs were derived from the published SQGs. These SQGs reflect the toxicity of sediment-associated contaminants when they occur in mixtures with other contaminants. Therefore, these consensus-based SQGs are likely to be directly relevant for assessing freshwater sediments that are influenced by multiple sources of contaminants. The results of the evaluations of predictive ability demonstrate that the TECs and PECs for most of these chemicals, as well as the PEC quotients, provide a reliable basis for classifying sediments as not toxic and toxic. In addition, positive correlations between sediment chemistry and sediment toxicity indicate that many of these sediment-associated contaminants are associated with the effects that were observed in field-collected sediments. Furthermore, the level of agreement between the available dose-response data, the EqP-based SQGs, and the consensus-based SQGs indicates that sediment-associated contaminants are likely to cause or substantially contribute to, as opposed to simply be associated with, sediment toxicity at concentrations above the PECs.

Overall, the results of the various evaluations demonstrate that the consensus-based SQGs provide a unifying synthesis of the existing SQGs, reflect causal rather than correlative effects, and account for the effects of contaminant mixtures (Swartz 1999). As such, the SQGs can be used to identify hot spots with respect to sediment contamination, determine the potential for and spatial extent of injury to sediment-dwelling organisms, evaluate the need for sediment remediation, and support the development of monitoring programs to further assess the extent of contamination and the effects of contaminated sediments on sediment-dwelling organisms. These applications are strengthened when the SQGs are used in combination with other sediment quality assessment tools (*i.e.*, sediment toxicity tests, bioaccumulation assessments, benthic invertebrate community assessments; Ingersoll *et al.* 1997). In these applications, the TECs should be used to identify sediments that are unlikely to be adversely affected by sediment-associated contaminants. In contrast, the PECs should be used to identify sediments that are likely to be toxic to sediment-dwelling

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Region 5 RCRA Corrective Action

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Ecological Screening Levels

A requirement of the RCRA Corrective Action and Permit programs within Region 5 is that adverse risk to the environment be evaluated and controlled. This risk is determined through an ecological risk assessment and the Region 5, RCRA Ecological Screening Levels (ESLs) is the initial tool employed. The ESLs represent a protective benchmark (e.g., water quality criteria, sediment quality guidelines/ criteria, and chronic no adverse effect levels) for 223 contaminants (based on the RCRA 40 CFR 264 Appendix IX list of hazardous substances) and four environmental media (i.e., air, water, sediment and soil). An initial risk screen will identify those contaminants that exceed the ESL benchmarks which will be retained for additional analysis and allow the investigation to focus on those areas likely to present an unacceptable risk. When an endangered species and/or its habitat is identified, specific concerns regarding contaminant exposure to these species needs to be addressed. Quality assurance data requirements for field investigations are influenced by the ESL concentration. The ESLs (previously known as ecological data quality levels or EDQLs) are not intended to serve as cleanup levels. Please note that EDQLs were intended to function as screening levels.

The August 2003 update of the ESL table focuses on the water and sediment data. Many of the water and sediment benchmarks have been revised using current information and are displayed in bold font and a reference is provided for all of the water and sediment data. Of the 102 new water ESLs 50 are lower and for the 99 new sediment ESLs 40 are lower. All of the new ESLs with lower data values are identified with a footnote. Some ESL values were deleted from the table when supporting data was inadequate and are noted with a dashed line (e.g., ----). The method reporting limit (MRL) data was also deleted from the table as it was designed to support data quality requirements for human health criteria and several of the methods employed to develop the MRLs have been revised. A summary report will be created on the development of soil benchmarks along with equations, criteria and references. Likewise, a report will be prepared on the development of water benchmarks that are based on mink and belted kingfisher exposure.

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Region 5 Waste Areas

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U.S. EPA, Region 5, RCRA

Ecological Screening Levels

August 22, 2003

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Acenaphthene	83-32-9		**38**[a]	6.71[r]	6.82 e+5
Acenaphthylene	208-96-8		4.84 e+3[b]	5.87[r]	6.82 e+5
Acetone	67-64-1	959	**1700**[a, c, z]	**9.9**[z]	2500[w]
Acetonitrile	75-05-8	17.1	**12 e+3**[d, z]	**56**[z]	1370[w]
Acetophenone	98-86-2		-----	-----	3 e+5
Acetylaminofluorene [2-]	53-96-3		535[b]	15.3	596
Acrolein	107-02-8	0.578	**0.19**[c, z]	**1.52 e-3**[z]	5270[w]
Acrylonitrile	107-13-1	0.797	**66**[a]	**1.2**	23.9[w]
Aldrin	309-00-2		**1.7 e-2**[a, z]	2[t]	3.32[x]
Allyl chloride	107-05-1	1.22		-----	13.4
Aminobiphenyl [4-]	92-67-1			-----	3.05
Aniline	62-53-3		**4.1**[d]	**0.31**	56.8[w]
Anthracene	120-12-7		**0.035**[f]	**57.2**[u]	1.48 e+6
Antimony (Total)	7440-36-0		**80**[c]		142
Aramite	140-57-8		3.09[g]	1.11 e-3	1.66 e+5
Arsenic (Total)	7440-38-2		**148**[f]	**9790**[u]	5700
Azobenzene [p-(dimethylamino)]	60-11-7		1.65[b]	318	40
Barium (Total)	7440-39-3		**220**[d, z]		1040
Benzene	71-43-2	9.76	114[f]	142	255
Benzo[a]anthracene	56-55-3		**0.025**[c, z]	**108**[u]	5210

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Benzo[a]pyrene	50-32-8		0.014[h]	**150**[u]	1520
Benzo[b]fluoranthene	205-99-2		9.07[b]	1.04 e+4	5.98 e+4
Benzo[ghi]perylene	191-24-2		7.64[b]	170[t]	1.19 e+5
Benzo[k]fluoranthene	207-8-9		-----	240[t]	1.48 e+5
Benzyl alcohol	100-51-6		**8.6**[h, z]	**1.04**[z]	6.58 e+4
Beryllium (Total)	7440-41-7		**3.6**[d, k, z]		1060
BHC [alpha-]	319-84-6		12.4[b]	6[t]	99.4
BHC [beta-]	319-85-7		0.495[b]	5[t]	3.98[x]
BHC [delta-]	319-86-8		667[g]	7.15 e+4	9940
BHC [gamma-]	58-89-9		**0.026**[a]	**2.37**[u]	5[x]
Bromodichloromethane	75-27-4			-----	540
Bromoform	75-25-2	9.11	**230**[d, z]	**492**[z]	1.59 e+4
Bromophenyl phenyl ether [4-]	101-55-3		1.5[h]	1550	
Butylamine [N-Nitrosodi-n-]	924-16-3		-----	-----	267
Butylbenzyl phthalate	85-68-7		**23**[d, z]	**1970**[z]	239
Cadmium (Total)	7440-43-9		**0.15**[i, j, k]	**990**[u]	2.22
Carbon disulfide	75-15-0	3.67	**15**[d, z]	**23.9**[z]	94.1
Carbon tetrachloride	56-23-5	1.41	**240**[d]	**1450**	2980
Chlordane	57-74-9		**4.3 e-3**[j]	**3.24**[u, z]	224[x]
Chlorethyl ether [bis(2-]	111-44-4		**19 e+3**[l]	**3520**	2.37 e+4[w]

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Chloro-1-methylethyl)ether [bis(2-]	108-60-1		-----	-----	1.99 e+4
Chloroaniline [p-]	106-47-8		232[g]	146	1100
Chlorobenzene	108-90-7	120	**47**[a]	**291**	1.31 e+4
Chlorobenzilate	510-15-6		7.16[g]	860	5050
Chloroethane	75-0-3	20	-----	-----	
Chloroform	67-66-3	1.34	**140**[d]	**121**	1190
Chloronaphthalene [2-]	91-58-7		0.396[b]	417	12.2
Chlorophenol [2-]	95-57-8		**24**[a]	**31.9**	243
Chlorophenyl phenyl ether [4-]	7005-72-3			-----	
Chloroprene	126-99-8	4.16 E-2		-----	2.9
Chromium^{+3} (Total)	7440-47-3		42[j, k]	**4.34 e+4**[u]	400[y]
Chrysene	218-1-9		-----	**166**[u]	4730
Cobalt (Total)	7440-48-4		**24**[d]	5.00 e+4[l]	140
Copper (Total)	7440-50-8		**1.58**[j, k, z]	**3.16 e+4**[u]	**5400**
Cresol [4,6-dinitro-o-]	534-52-1		**23**[m]	**104**	144
Cresol [m-]	108-39-4		**62**[d]	**52.4**	3490
Cresol [o-]	95-48-7		**67**[c]	**55.4**	4.04 e+4
Cresol [p-chloro-m-]	59-50-7		34.8[g]	388	7950
Cresol [p-]	106-44-5		**25**[a]	**20.2**	1.63 e+5
Cyanide	57-12-5		5.2[a]	0.1[l]	1330[w]

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
DDD [4,4'-]	72-54-8		-----	**4.88**[u,z]	758
DDE [4,4'-]	72-55-9		4.51 e-9[c]	**3.16**[u]	596
DDT [4,4'-]	50-29-3		**1.1 e-5**[a,z]	**4.16**[u]	**3.5**[z]
Di-n-butyl phthalate	84-74-2		**9.7**[a]	**1114**	150
Di-n-octyl phthalate	117-84-0		30[f]	4.06 e+4	7.09 e+5
Diallate	2303-16-4		-----	-----	452[w]
Dibenzofuran	132-64-9		**4**[a,z]	**449**[z]	
Dibenz[a,h]anthracene	53-70-3		-----	**33**[u]	1.84 e+4
Dibromo-3-chloropropane [1,2-]	96-12-8	0.32	-----	-----	35.2
Dibromochloromethane	124-48-1		-----	-----	2050
Dibromoethane [1,2-]	106-93-4	176	-----	-----	1230
Dichloro-2-butene [trans-1,4-]	110-57-6	4.03		-----	
Dichlorobenzene [m-]	541-73-1	273	**38**[a,z]	**1315**[z]	3.77 e+4
Dichlorobenzene [o-]	95-50-1	270	**14**[h]	**294**	2960
Dichlorobenzene [p-]	106-46-7	275	**9.4**[d,z]	**318**[z]	546
Dichlorobenzidine [3,3'-]	91-94-1		**4.5**[a,z]	**127**	646
Dichlorodifluoromethane	75-71-8	1550		-----	3.95 e+4
Dichloroethane [1,1-]	75-34-3	1240	47[h]	0.575	2.01 e+4
Dichloroethane [1,2-]	107-6-2	29.7	**910**[h]	**260**	2.12 e+4
Dichloroethene [1,1-]	75-35-4	0.303	**65**[a,z]	**19.4**[z]	8280

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment^{s} ug/kg	Soil^{v} ug/kg
Dichloroethylene [trans-1,2-]	156-60-5	29.1	**970^{d}**	**654**	784
Dichlorophenol [2,4-]	120-83-2		**11^{d,z}**	**81.7^{z}**	8.75 e+4
Dichlorophenol [2,6-]	87-65-0			-----	1170
Dichloropropane [1,2-]	78-87-5	70.6	**360^{a,z}**	**333^{z}**	3.27 e+4
Dichloropropene [cis-1,3-]	10061-1-5	5.89	-----	-----	398
Dichloropropene [trans-1,3-]	10061-2-6	5.89	-----	-----	398
Dieldrin	60-57-1		**7.1 e-5^{a}**	**1.9^{u,z}**	2.38
Diethyl O-2-pyrazinyl phosphorothioate [O,O-]	297-97-2			-----	799
Diethyl phthalate	84-66-2		**110^{a}**	**295**	2.48 e+4
Dimethoate	60-51-5		-----	-----	218
Dimethyl phthalate	131-11-3		-----	-----	7.34 e+5
Dimethylbenzidine [3,3'-]	119-93-7			-----	104
Dimethylbenz[a]anthracene [7,12-]	57-97-6		0.548^{b}	6.64 e+4	1.63 e+4
Dimethylphenethylamine [alpha,alpha-]	122-9-8			-----	300
Dimethylphenol [2,4-]	105-67-9		100^{b}	304	10^{x}
Dinitrobenzene [m-]	99-65-0		**22^{d}**	**8.61**	655
Dinitrophenol [2,4-]	51-28-5		**19^{a}**	**6.21**	60.9
Dinitrotoluene [2,4-]	121-14-2		**44^{d,z}**	**14.4^{z}**	1280
Dinitrotoluene [2,6-]	606-20-2		**81^{d}**	**39.8**	32.8

Chemical	CAS No.	Air mg/m³	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Dinoseb	88-85-7		**0.48**[a]	**14.5**	21.8
Dioxane [1,4-]	123-91-1	367	**22 e+3**[a]	**119**	2050[w]
Diphenylamine	122-39-4		412[b]	34.6	1010
Disulfoton	298-4-4		4.02 e-2[c]	324	19.9
D [2,4-]	94-75-7		**220**[a]	**1273**	27.2
Endosulfan I	959-98-8		**0.056**[j]	**3.26**	119
Endosulfan II	33213-65-9		**0.056**[j]	**1.94**	119
Endosulfan sulfate	1031-7-8		2.22[b]	34.6	35.8
Endrin	72-20-8		**0.036**[a]	**2.22**[u, z]	10.1
Endrin aldehyde	7421-93-4		0.15[b]	**480**[z]	10.5
Ethyl methacrylate	97-63-2	356		-----	3 e+4
Ethyl methane sulfonate	62-50-0			-----	
Ethylbenzene	100-41-4	304	**14**[o, z]	**175**	5160
Famphur	52-85-7			-----	49.7
Fluoranthene	206-44-0		**1.9**[f, z]	**423**[u]	1.22 e+5
Fluorene	86-73-7		**19**[d]	**77.4**[u]	1.22 e+5
Heptachlor	76-44-8		**3.8 e-3**[j]	0.6[r]	5.98
Heptachlor epoxide	1024-57-3		**3.8 e-3**[j]	**2.47**[u]	152
Hexachlorobenzene	118-74-1		**3 e-4**[a]	20[r]	199
Hexachlorobutadiene	87-68-3		**0.053**[a, z]	**26.5**[z]	39.8

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Hexachlorocyclopentadiene	77-47-4		77[b]	901	755
Hexachloroethane	67-72-1		**8**[a, z]	**584**[z]	596
Hexachlorophene	70-30-4		0.228[c]	2.31 e+5	199
Hexachloropropene	1888-71-7		-----	-----	
Hexanone [2-]	591-78-6	105	**99**[h, z]	**58.2**[z]	1.26 e+4
Indeno (1,2,3-cd) pyrene	193-39-5		4.31[b]	200[l]	1.09 e+5
Isobutyl alcohol	78-83-1	32.8	-----	-----	2.08 e+4[w]
Isodrin	465-73-6		3.09 e-2[c]	55.2	3.32[x]
Isophorone	78-59-1		**920**[d]	**432**	1.39 e+5
Isosafrole	120-58-1			-----	9940
Kepone	143-50-0		0.132[c]	3.31	32.7
Lead (Total)	7439-92-1		**1.17**[j, k, z]	**3.58 e+4**[u]	53.7
Mercury (Total)	7439-97-6		1.3 e-3[a]	174[r]	100[y]
Methacrylonitrile	126-98-7	3.38		-----	57[w]
Methane [bis(2-chloroethoxy)]	111-91-1		-----	-----	302[w]
Methapyrilene	91-80-5			-----	2780[w]
Methoxychlor	72-43-5		**0.019**[h]	**13.6**	19.9
Methyl bromide	74-83-9	26.5	**16**[d]	**1.37**	235[w]
Methyl chloride	74-87-3	2.63		-----	1.04 e+4[w]
Methyl ethyl ketone	78-93-3	642	**2200**[a, z]	**42.4**[z]	8.96 e+4[w]

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Methyl iodide	74-88-4	11.7		-----	1230
Methyl mercury	22967-92-6		2.46 e-3[c]	0.01	1.58
Methyl methacrylate	80-62-6	87.1	2800[g]	168	9.84 e+5[w]
Methyl methanesulfanate	66-27-3			-----	315[w]
Methyl parathion	298-0-0			-----	0.292
Methyl-2-pentanone [4-]	108-10-1	45.9	**170**[h, z]	**25.1**[z]	4.43 e+5
Methylcholanthrene [3-]	56-49-5		8.91 e-2[b]	8.19 e+6	77.9
Methylene bromide	74-95-3	344		-----	6.5 e+4[w]
Methylene chloride	75-9-2	4780	**940**[a]	**159**[z]	4050[w]
Methylnaphthalene [2-]	91-57-6		330[b]	20.2[r]	3240
Naphthalene	91-20-3	80.1	**13**[a, z]	**176**[u]	99.4
Naphthoquinone [1,4-]	130-15-4		-----	-----	1670
Naphthylamine [1-]	134-32-7		-----	-----	9340
Naphthylamine [2-]	91-59-8			-----	3030
Nickel (Total)	7440-2-0		**28.9**[j, k, z]	**2.27 e+4**[u]	1.36 e+4
Nitroaniline [m-]	99-9-2			-----	3160
Nitroaniline [o-]	88-74-4			-----	7.41 e+4
Nitroaniline [p-]	100-1-6			-----	2.19 e+4
Nitrobenzene	98-95-3		**220**[n, z]	**145**[z]	1310
Nitrophenol [o-]	88-75-5		-----	-----	1600

Chemical	CAS No.	Air mg/m^3	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Nitrophenol [p-]	100-2-7		**60[a]**	**13.3**	5120
Nitroquinoline-1-oxide [4-]	56-57-5			-----	122
Nitrosodiethylamine [N-]	55-18-5		768[g]	22.8	69.3[w]
Nitrosodimethylamine [N-]	62-75-9			-----	0.0321[w]
Nitrosodiphenylamine [N-]	86-30-6		-----	-----	545
Nitrosomethylethylamine [N-]	10595-95-6			-----	1.66[w]
Nitrosomorpholine [N-]	59-89-2			-----	70.6[w]
Nitrosopiperidine [N-]	100-75-4			-----	6.65[w]
Nitrosopyrrolidine [N-]	930-55-2			-----	12.6[w]
Parathion	56-38-2		**0.013[a, d]**	**0.757**	0.34[y]
Pentachlorobenzene	608-93-5		**0.019[a, z]**	**24[z]**	497
Pentachloroethane	76-1-7	0.68	56.4[g]	689	1.07 e+4
Pentachloronitrobenzene	82-68-8		-----	-----	7090
Pentachlorophenol	87-86-5		**4.0[j, p, z]**	**2.3 e+4[z]**	119
Phenacetin	62-44-2		-----	-----	1.17 e+4
Phenanthrene	85-1-8		**3.6[f]**	**204[u]**	4.57 e+4
Phenol	108-95-2	4.31	**180[c]**	**49.1**	1.2 e+5
Phenylenediamine [p-]	106-50-3			-----	6160[w]
Phorate	298-02-2		3.62[g]	0.861	0.496
Phthalate [bis(2-ethylhexyl)]	117-81-7		**0.3[q, z]**	182[r]	925

Chemical	CAS No.	Air mg/m³	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Picoline [2-]	109-6-8	140	-----	-----	9900[w]
Polychlorinated biphenyls	1336-36-3		**1.2 e-4**[a, z]	**59.8**[u]	0.332
Polychlorinated dibenzo-p-dioxins	PCDD-S		2.78 e-7[b]	**0.011**	1.99 e-4
Polychlorinated dibenzofurans	51207-31-9		-----	-----	0.0386
Pronamide	23950-58-5		-----	-----	13.6[x]
Propionitrile	107-12-0	1.87	-----	-----	49.8[w]
Propylamine [N-nitrosodi-n-]	621-64-7			-----	544
Pyrene	129-0-0		0.3[g]	**195**[u]	7.85 e+4
Pyridine	110-86-1	13.7	2380[g]	106	1030[w]
Safrole	94-59-7		-----	-----	404
Selenium (Total)	7782-49-2		5[j]		27.6
Silver (Total)	7440-22-4		**0.12**[f, z]	500[l]	4040
Silvex	93-72-1		**30**[a, z]	**675**[z]	109[x]
Styrene	100-42-5	0.946	**32**[d, z]	**254**[z]	4690
Sulfide	18496-25-8				3.58
Tetrachlorobenzene [1,2,4,5-]	95-94-3		**3**[a, z]	**1252**[z]	2020
Tetrachlorodibenzo-p-dioxin [2,3,7,8-]	1746-1-6		**3 e-9**[a, z]	**1.2 e-4**[z]	1.99 e-4
Tetrachloroethane [1,1,1,2-]	630-20-6	22.5	-----	-----	2.25 e+5
Tetrachloroethane [1,1,2,2-]	79-34-5	353	**380**[a]	**850**	127
Tetrachloroethene	127-18-4	69	**45**[a]	**990**	9920

Chemical	CAS No.	Air mg/m³	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Tetrachlorophenol [2,3,4,6-]	58-90-2		**1.2[a,z]**	**129[z]**	199
Tetraethyl dithiopyrophosphate	3689-24-5		13.9[b]	560	596
Thallium (Total)	7440-28-0		**10[a]**		56.9
Tin (Total)	7440-31-5		**180[d]**		7620
Toluene	108-88-3	1040	253[f]	**1220[z]**	5450
Toluidine [5-nitro-o-]	99-55-8			-----	8730
Toluidine [o-]	95-53-4			-----	2970[w]
Toxaphene	8001-35-2		**1.4 e-4[a,z]**	**0.077[z]**	119
Trichlorobenzene [1,2,4-]	120-82-1		**30[a,z]**	**5062[z]**	1.11 e+4
Trichloroethane [1,1,1-]	71-55-6	4170	**76[d,z]**	**213[z]**	2.98 e+4
Trichloroethane [1,1,2-]	79-0-5	11.6	**500[a,z]**	**518[z]**	2.86 e+4
Trichloroethylene	79-1-6	1220	**47[h,z]**	**112[z]**	1.24 e+4
Trichlorofluoromethane	75-69-4	5150		-----	1.64 e+4
Trichlorophenol [2,4,5-]	95-95-4			-----	1.41 e+4
Trichlorophenol [2,4,6-]	88-6-2		**4.9[d]**	**208**	9940
Trichloropropane [1,2,3-]	96-18-4	3.32	-----	-----	3360
Trichlorphenoxyacetic acid [2,4,5-]	93-76-5		686[g]	5.87 e+4	596
Triethyl phosphorothioate [O,O,O-]	126-68-1		58.2[b]	189	818
Trinitrobenzene [Sym-]	99-35-4			-----	376[w]
Vanadium (Total)	7440-62-2		**12[a,z]**		1590

Chemical	CAS No.	Air mg/m³	Water ug/l	Sediment[s] ug/kg	Soil[v] ug/kg
Vinyl acetate	108-5-4	359	248[g]	13	1.27 e+4[w]
Vinyl chloride	75-1-4	0.221	**930**[a]	**202**	646
Xylenes (total)	1330-20-7	135	**27**[d, z]	**433**[z]	1 e+4[x]
Zinc (Total)	7440-66-6		**65.7**[j, k, z]	**1.21 e+5**[u]	6620[y]

[a] = Michigan water quality standards, Rule 57 water quality values, July 23, 2003. Available at: http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3728-11383--,00.html. The water ESL data for acenaphthene, BHC (gamma), cyanide and parathion are Michigan (final chronic value or FCV) Tier I criteria. Likewise, water ESL data for dieldrin, dioxin, DDT, endrin, hexachlorobenzene, hexachlorobutadiene, mercury, PCB's and toxaphene represent wildlife values (see Notes at end of these footnotes for dioxin, DDT, mercury and PCB's). All of the remaining data are Tier II values.

[b] = Water Ecological Screening Level (ESL) based on exposure to a mink (*Mustela vison*).

[c] = Indiana water quality standards, Title 327, Article 2, of the Indiana Administrative Code, Feb. 4, 2002. Available at: http://www.ai.org/legislative/iac/t03270/a00020.pdf The water ESL for toxaphene is from the Indiana chronic aquatic criterion for all waters outside of mixing zones (see Table 1 under Rule 1 of 327 IAC 2-1-6 Minimum Surface Water Quality Standards at the above Internet site). The remaining water ESL data are either wildlife values (for dioxin, DDT, mercury and PCB's) or Tier II values for the Indiana Great Lakes Basin (see Great Lakes Basin Criteria and Values Table as developed under Rule 1.5 of 327 IAC Article 2 as referenced above).

[d] = Ohio water quality standards, Chapter 3745-1 of the Ohio Administrative Code, Dec. 30, 2002. Available at: http://www.epa.state.oh.us/dsw/rules/3745-1.html The water ESL data for endrin and parathion are Ohio aquatic life Tier I criteria from the Outside Mixing Zone Average (OMZA). Wildlife values are available for dioxin, DDT, mercury and PCB's. All of the remaining data are Ohio aquatic life Tier II values from the OMZA. See Ohio summary tables for water quality criteria and values along with reference on the development of Tier I criteria and Tier II values.

[e] = Water ESL based on exposure to a belted kingfisher (*Ceryle alcyon*).

[f] = Minnesota water quality standards, Rule 7052.0100, Subpart 2 (water ESL data for arsenic & benzene represents aquatic life chronic standards and dioxin, DDT, mercury and PCB's represents wildlife values), April 13, 2000. Rule 7050.0222, Subpart 2, Feb. 12, 2003. Available at: http://www.revisor.leg.state.mn.us/arule/7050/0100.html and http://www.revisor.leg.state.mn.us/arule/7052/0222.html

[g] = Region 5, RCRA Interim Criteria, based on Aquire database with acceptable review codes and endpoints (life cycle). Must have eight or more acceptable studies (i.e., chronic and/or acute).

[h] = GLWQI Tier II value as presented in: Suter, G.W. II and Tsao, C.L. 1996. Toxicological benchmarks for screening potential contaminants of concern for effects on aquatic biota, 1996 Revision. ES/ER/TM-96/R2. Available at: http://www.esd.ornl.gov/programs/ecorisk/ecorisk.html

[i] = U.S. EPA 2001 Update of Ambient Water Quality Criteria for Cadmium (EPA 822-R-01-001).

[j] = U.S. EPA National Recommended Water Quality Criteria: 2002 (EPA 822-R-02-047)

[k] = For hardness-dependent metals (beryllium, cadmium, chromium^{+3}, copper, lead, nickel and zinc), freshwater chronic criteria are based on soft water with a total hardness of 50 mg/L as $CaCO_3$. Soft water is common within Region 5 and this water ESL may be recalculated when site specific water hardness is less than 50 mg/L.

[l] = U.S. EPA Ambient Water Quality for Chloroalkyl Ethers (EPA 440/5-80-030). No definitive data available concerning chronic toxicity. The water ESL is based on no adverse effects for a chronic toxicity embryo-larval test of the fathead minnow.

[m] = U.S. EPA Ambient Water Quality for Nitrophenols (EPA 440/5-80-063). The acute value of 230 ug/l was adjusted with an uncertainty factor of ten for 2,4-dinitrophenol and 4,6-dinitro-o-cresol since no chronic criteria are available.

[n] = Wisconsin Surface Water Quality Criteria and Secondary Values for Toxic Substances, NR 105.07(1)(b), Sept.1, 1997. Available at: http://www.legis.state.wi.us/rsb/code/nr/nr100.html

[o] = Illinois water quality standards, Title 35, Part 302.208, Dec. 20, 2002. Available at: http://www.ipcb.state.il.us/SLR/IPCBandIEPAEnvironmentalRegulations-Title35.asp

[p] = The criterion for pentachlorophenol is pH dependent and is based on a pH of 6.5.

[q] = U.S. EPA Ambient Water Quality for Phthalate Esters (EPA 440/5-80-067). A chronic value of 3 ug/L that resulted in significant reproductive impairment was adjusted with an uncertainity factor of ten.

[r] = Environment Canada. September 1994. Interim Sediment Quality Assessment Values. Ecosystem Conservation Directorate. Evaluation and Interpretation Branch.

[s] = Unless noted otherwise, all Sediment ESLs were derived using equilibrium partitioning (EqP) equation and the corresponding water ESL. Note: Sediment ESL = K_{oc} x Water ESL x 0.01.

[t] = Ontario Ministry of the Environment. August 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario.

[u] = Consensus based threshold effect concentrations (TEC) as presented in MacDonald et. al. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch Environ Contam Toxicol 39:20-31 (see Table 2). The TEC for mercury had a high incidence of toxicity and was not used. These values do not consider bioaccumulation nor biomagnification.

[v] = Unless noted otherwise, all Soil ESLs are based on exposure to a masked shrew (*Sorex cinerus*).

[w] = Soil ESL is based on exposure to a meadow vole (*Microtus pennsylvanicus*).

[x] = Soil ESL is based on exposure to a plant.

[y] = Soil ESL is based on exposure to soil invertebrates (e.g., earthworms).

[z] = New ESL data is lower than the previous table.

Notes: New ESL data are displayed in bold font and a dashed line (e.g., -----) is used to show when data was deleted from the previous table (i.e., supporting data was inadequate). All six states in EPA Region 5 have the same water ESL's for dioxin, DDT, mercury and PCB's which are based on a wildlife value. A summary report will be created on the development of soil benchmarks including equations, criteria and references. Likewise, a report will be prepared on the development of water benchmarks that are based on mink and belted kingfisher exposure.

RISK-BASED STANDARDS FOR KANSAS
RSK MANUAL – 3rd VERSION

MARCH 1, 2003

KANSAS DEPARTMENT OF HEALTH AND ENVIRONMENT

DIVISION OF ENVIRONMENT

BUREAU OF ENVIRONMENTAL REMEDIATION

PREFACE:

The Risk-Based Standards for Kansas (RSK) Manual was developed to assist Kansas Department of Health and Environment (KDHE)/Bureau of Environmental Remediation project managers to fairly and consistently address contaminated sites in the State of Kansas. The manual is only applicable to contaminated properties or sites that are participating in an appropriate state program. KDHE project managers will work with responsible parties to ensure appropriate application of this guidance.

This document is not intended to be used for environmental audits, environmental assessments or other non-KDHE managed activities. Use of Tier 2 values established in the RSK Manual without KDHE oversight may constitute misapplication of the RSK Manual and may result in risk management decisions not supported by KDHE.

This March 1, 2003 RSK Manual supercedes the September 4, 2001 version. The September 4, 2001 version is obsolete and should not be used for future decisions related to the characterization or remediation of contaminated properties/sites. This March 1, 2003 version of the RSK Manual contains several updates to the existing text, tables, and appendices. Modifications to the text are mostly of an editorial nature, although text has been added to Section 6.0 to better describe the use of soil saturation values for total petroleum hydrocarbons (TPH). Also, an entirely new discussion on nitrate and ammonia contamination is presented in Section 7.0.

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RISK-BASED STANDARDS FOR KANSAS

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RISK-BASED STANDARDS FOR KANSAS

1.0 INTRODUCTION

The Risk-Based Standards for Kansas (RSK) Manual is a guidance document which describes the process for establishing chemical-specific and site-specific cleanup goals for soil and ground water that are protective of human health and the environment. This document was created to establish a consistent and streamlined decision making process for addressing contaminated sites managed by the Kansas Department of Health and Environment (KDHE)/Bureau of Environmental Remediation (BER). The RSK Manual is meant to serve as a tool for evaluation of site conditions and the need for additional assessment or cleanup, when considered in conjunction with other site-specific conditions. The RSK Manual is a compilation of federal Safe Drinking Water Act Maximum Contaminant Levels (MCLs) for public drinking water supplies, risk-based cleanup goals for contaminants in soil and ground water for which federal standards have not been established, and supporting chemical, physical, and toxicological properties for the contaminants considered herein.

The procedures and methodologies contained in this document have been employed to be consistent with federal guidance and directives to assess potential human health risk posed by exposure to environmental contamination. Federal guidance and directives were established subsequent to the promulgation of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). KDHE believes that proper employment of this manual will result in risk-based remediation that is consistent with federally promulgated standards, including the Safe Drinking Water Act, and is protective of human health as defined by the National Contingency Plan (NCP).

The document was developed through collaboration with CH2M Hill, a private environmental contractor with expertise in risk assessments. Chemical-specific and media-specific risk-based cleanup goals were calculated using guidance and directives from the United States Environmental Protection Agency (EPA) and other technical resources, which are referenced throughout this document and listed in Section 9, "REFERENCES." This document is the third edition of "Risk-Based Standards for Kansas," originally dated March 29, 1999, and supercedes all previous editions.

2.0 PUBLIC USE OF RSK

The primary benefit of this document is the predetermination of acceptable cleanup goals without requiring the performance of costly and time-consuming baseline risk assessments and/or contaminant fate and transport models. Use of the RSK Manual offers many other benefits to Kansas industry, Kansas residents, and KDHE, including:

BENEFITS OF THE RSK MANUAL:

- Streamlines the decision-making process;
- Promotes consistency;
- Ensures that remedial actions are protective of human health and the environment;
- Promotes flexibility by providing tabulated risk-based cleanup goals as well as the opportunity to develop site-specific cleanup goals;
- Considers land use; and,
- Provides the opportunity for the use of institutional controls and/or financial assurance to ensure that contamination remaining on site will not pose a future threat.

The document provides the public with a streamlined, cost-effective approach to determine whether some form of remedial action is warranted at a contaminated site. **Direct oversight and approval by KDHE in this determination is required.** The implementation or use of this document without the direct oversight and consent of KDHE does not constitute or convey the determination that no action is warranted at a contaminated site. Additional state, federal, and/or local laws or regulations may be applicable at certain sites. The user is responsible for compliance with these laws and regulations, and to obtain all applicable permits, approvals, authorizations, etc. The final selection of cleanup levels shall rest with the department. KDHE urges the public to consider the following when using the RSK document:

- Applicable or relevant and appropriate requirements may affect the selection or implementation of a cleanup approach for the site, i.e., zoning for land use designation, local public health laws and ordinances, ground water management districts, Resource Conservation and Recovery Act (RCRA), etc.;
- There may be additive effects posed by multiple contaminants and multiple pathways of exposure;
- Aesthetic or other criteria may drive the need for remediation independent of risk-based standards;
- KDHE's oversight and approval must be obtained to ensure that actions conducted at the site are consistent with and satisfy state laws, rules and regulations, guidance, and policies; and,
- The RSK Manual does not address the potential health risks associated with migration of contaminants from soil and ground water into indoor air.

3.0 OVERVIEW

The RSK Manual provides an overview of the rationale and process for determining soil and ground water cleanup levels for contaminated sites in Kansas. Detailed information on definitions, formulas, input parameters and the use of the three tiers are provided in the following sections. **This approach is not acceptable for all sites, so approval must be obtained from the state program responsible for regulating the site.**

- **TIER 1** – KDHE-approved methods to determine background concentrations;
- **TIER 2** – KDHE/BER Risk-Based Summary Table; or
- **TIER 3** – Site-specific technical analyses using KDHE-approved information, data, models, model input parameters or other methodologies to determine site-specific remedial actions or cleanup concentrations.

Human health risk is best described as the probability of suffering harm as a consequence of chronic, or long-term, exposure to contaminated media. Human health risk effects are generally classified into two separate categories. *Non-carcinogens* are contaminants that lack evidence of increasing the potential for developing cancer over a lifetime. *Carcinogens* are contaminants that have the potential to increase the potential for developing cancer over the lifetime of an exposed individual.

For *non-carcinogens* a threshold concentration is quantified for each contaminant based upon clinically-determined critical toxicological effects such as liver damage, kidney damage, central nervous system disorders, etc. The threshold concentration is referred to as the reference dose or RfD. The lower the RfD value for a contaminant, the more toxic it is relative to contaminants with higher RfDs. Exposure to a contaminant concentration below the RfD should not cause a critical toxicological effect; however, exposure to a contaminant concentration exceeding the RfD may cause a critical toxicological effect. Risk assessors calculate the ratio of a contaminant concentration to the RfD to determine the Hazard Index (HI). If the HI is less than or equal to 1, the contaminant concentration is considered acceptable. If the HI is greater than 1, the contaminant concentration is considered unacceptable and a response action may be required.

For *carcinogens*, the probability of increasing the potential for developing a cancer as a result of chronic exposure to contaminated media is quantified based upon clinical studies of exposed populations, including humans, where available, or test animals in the absence of documented human exposures. The contaminant-specific carcinogenic risk factor is referred to as the slope factor. Contrary to RfDs, the higher the slope factor value for a carcinogenic contaminant, the more toxic it is relative to carcinogenic contaminants with lower slope factors. Risk assessors quantify the probability of developing a cancer as a result of chronic exposure to carcinogenic contaminated media by multiplying the contaminant concentration by the contaminant slope factor. The resulting value is expressed in terms of one additional cancer incidence per population exposed; for example, one additional cancer incidence per ten thousand (1 in 10,000) exposed individuals, which may be expressed as 1×10^{-4}. EPA regulations state the 1×10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when applicable or relevant and appropriate requirements (ARARs) are not available or are not sufficiently protective because of the presence of multiple contaminants or multiple pathways of exposure. Carcinogenic contaminants are also evaluated for their critical non-carcinogenic toxicological effect. The determining risk-based concentration is based upon the lower contaminant concentration of the carcinogenic risk or non-carcinogenic risk.

Soil cleanup goals are based upon one or more of the following considerations as defined in the various program policies and regulations. The primary goal of Bureau of Environmental Remediation programs is to insure that sites are remediated to the extent that the public are protected from unreasonable risks potentially caused by exposure to contaminated sites.

1. In the event naturally occurring[1] levels of an individual contaminant in soil exceed the cancer risk of 1×10^{-6} (1 in 1,000,000), or a hazard index value of 1.0, then the background level may be the cleanup level;
2. In the event that anthropogenic[2] levels of a contaminant in soil exceed the cancer risk of 1×10^{-6} (1 in 1,000,000), or a hazard index value of 1.0, then a 1×10^{-5} (1 in 100,000) cancer risk level, or a level corresponding to a hazard index value equal to 1.0 may be used as the cleanup levels;
3. A property-specific risk analysis performed in accordance with the department's scope of work shall be used to determine a property-specific cleanup level where the cancer risk exceeds 1×10^{-6} or the hazard index value exceeds 1.0. This site-specific cleanup level may not pose cumulative cancer risk of greater than 1×10^{-4} or a hazard index of greater than 1.0. Where carcinogenic contaminants drive the need for cleanup, the department will determine the appropriate level of cleanup within the 1×10^{-4} to 1×10^{-6} range based on site-specific considerations.
4. Property-specific cleanup levels shall be determined by the department for contaminants for which there is insufficient toxicological evidence to support a regulatory standard for risk-based cleanup levels or for nontoxic contaminants for which cleanup is required as a result of other undesirable characteristics of those contaminants. The levels shall be based on the following:

   a) The ability of the impacted soil to support vegetation representative of non-impacted properties in the vicinity of the eligible property; and,

   b) The potential of the contaminant to impact and degrade ground water, surface water, or both, through infiltration or runoff; and,
5. When there are multiple contaminants in the soil, the cleanup level of each contaminant shall not allow the cumulative risks posed by the contaminants to exceed a cancer risk of 1×10^{-4} (1 in 10,000), or a hazard index value of 1.0.

Ground water cleanup levels shall be based on the most beneficial use of the ground water considering present and proposed future uses. The most beneficial use of the ground water is for a potable water source, unless demonstrated otherwise by the voluntary party and approved by

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[1] *Naturally occurring chemicals or substances are defined as those chemicals or substances that are present in the environment at ambient concentrations unaffected by anthropogenic influences.*

[2] *Anthropogenic concentrations of chemicals or substances are defined as those chemicals or substances that are present in the environment as a result of human activity.*

the department. The most beneficial use of ground water shall be determined by the department based upon available documentation, as well as documentation provided by the potentially responsible party. Ground water potentially or actually used as a potable water source shall require maximum protection in determining cleanup levels. The department shall approve cleanup levels that prevent additional degradation of the groundwater caused by contamination migration and that encourage remedial actions to restore contaminated groundwater to its most beneficial use. One or a combination of the following approaches to ground water cleanup shall be proposed and approved by the department:

1. In the event naturally occurring levels of an individual contaminant in ground water exceed the cancer risk of 1×10^{-6} (1 in 1,000,000), or a hazard index value of 1.0; then the background level may be the cleanup level;

2. In the event that anthropogenic levels of an individual contaminant in ground water exceed the cancer risk level of 1×10^{-6} (one 1 in 1,000,000), or a hazard index value of 1.0, then the maximum contaminant levels (MCLs) established by the federal government or a cancer risk level of 1×10^{-5} (1 in 100,000), or a level corresponding to a hazard index value equal to 1.0 shall be the cleanup level;

3. In the event that the chemical-specific maximum contaminant levels (MCLs) are not applicable or available, a property-specific risk analysis performed by the voluntary party in accordance with the department's scope of work shall be used to determine a property-specific cleanup level where the cancer risk exceeds 1×10^{-6} or the hazard index value exceeds 1.0. The site-specific cleanup level may not pose cumulative cancer risk of greater than 1×10^{-4} or a hazard index of greater than 1.0. Where carcinogenic contaminants drive the need for cleanup, the department will determine the appropriate level of cleanup within the 1×10^{-4} to 1×10^{-6} range based on site-specific considerations.

4. When the need for cleanup of a contaminant is predicated on characteristics of that contaminant other than toxicity, including the contribution of an undesirable taste or odor, or both, the site-specific cleanup level as determined by the department or secondary MCLs shall be used as cleanup levels for contaminants for which insufficient toxicological evidence has been gathered to support a regulatory standard. These levels shall be based on the aesthetic quality and usability of the ground water, surface water, or both, for the present and proposed future use;

5. When there are multiple contaminants in the ground water, the cleanup level of each contaminant shall be such that the cumulative risks posed by the contaminants shall not exceed a cancer risk level of 1×10^{-4} (1 in 10,000), or a hazard index value of 1.0; and,

6. Surface water cleanup levels shall meet the Kansas surface water quality standards, as defined in K.A.R. 28-16-28(b), et seq.

4.0 SITE CHARACTERIZATION

Elements of a basic site characterization generally include record searches to gather historical information. That information will be used to focus the collection of environmental data, which in turn will be used to identify source(s) of contamination, delineate the horizontal and vertical extent of contamination, and characterize the geology, including significant contaminant fate and transport mechanisms. The information and data collected during site characterization should be sufficient to develop a site-specific conceptual model and support the evaluation and selection of a remedial response, if appropriate. The conceptual model should identify all media impacted by contamination (soil, ground water, surface water, etc.), primary and secondary exposure pathways, and exposed or potentially exposed populations. Site characterization information and data combined with a site-specific conceptual model are used to develop site-specific remedial action objectives.

The KDHE/BER has developed various scopes of work which define the tasks necessary to satisfy the objectives of various stages of site characterization, data needs for potential Tier 3 technical analyses, and information necessary to evaluate potential remedial alternatives. These scopes of work and associated guidance are available from each of the individual programs. Essential elements of any environmental site characterization typically include:

- A review of historical records to identify, at a minimum, all chemicals used at the site, chemical storage and handling area, and chemical product and waste disposal methods;
- A visual inspection of the facility or property to identify observable evidence of chemical releases, such as stained soil, stressed vegetation, corroded flooring, etc.;
- The collection of samples for laboratory analysis from environmental media at locations that are likely to have been impacted by historical release(s) of the contaminants of concern;
- The characterization of the geology and hydrology of the property using intrusive technologies such as soil borings and monitoring wells and the performance of aquifer tests to evaluate the composition and stratigraphy of the subsurface and the intrinsic hydrologic properties of the aquifer(s) underlying the site;
- The evaluation of the background concentrations of the contaminants of concern in affected environmental media; and,
- The identification of threatened or impacted receptors including, but not limited to, residents, workers, private and public water supply wells, sensitive ecosystems, etc.

For site investigations where naturally occurring chemicals or substances are the contaminants of concern, background or ambient environmental quality will need to be characterized. Background environmental quality characterization is necessary in order to identify the contaminants of concern and their appropriate site-specific cleanup goals. Failure to adequately characterize background environmental quality conditions may result in unnecessary cleanups.

If pre-existing background environmental quality data is not available or not representative of the site, then the collection and analysis of background samples will be required to determine background environmental quality. A site-specific number of soil samples, approved by KDHE, collected from the same soil type in an area nearest the site unaffected by potential releases of naturally occurring contaminants of concern should be analyzed to characterize background soil concentrations. For ground water, data should be collected at a location(s) representing background ground water quality conditions. If naturally occurring chemicals, or substances, which are potential contaminants of concern, based upon their usage, treatment, storage, or disposal, are detected at concentrations in excess of background, remedial action may be warranted.

Information collected during the site characterization should be sufficient to classify current and likely future land uses for the site. Chemical-specific cleanup concentrations defined in this document are based upon land use and are separated into two general land use scenarios, residential[3] and non-residential[4]. In general terms, all sites should be considered residential unless information provided within the site characterization proves otherwise and is approved by KDHE. Documentation of non-residential classification may include information from local zoning and planning department offices documenting the current and likely future land uses as non-residential. Non-residential sites located directly adjacent to residential properties shall be considered residential unless there are controls limiting access to the site such as security fencing. Land use shall be confirmed by KDHE by performing a site inspection.

After completing site characterization, including adequately assessing background environmental quality, chemical-specific goals can be determined for the site. The tiered approach outlined in the next section prescribes the process for determining cleanup goals for each site.

5.0 TIERED APPROACH

5.1 TIER 1

Tier 1 cleanup levels are determined for contaminants of concern that are naturally present in the environment. This class of contaminants includes metals such as lead, arsenic, cadmium, and chromium, among others, and inorganic pollutants such as nitrate and chloride, among others. In addition, certain substances that are endemically enriched in various environments, such as industrial tracts or agricultural lands as a result of their widespread employment by humans, may be evaluated as a Tier 1 contaminant. For sites with naturally-occurring contaminants, the background concentration shall be the cleanup level in soil and ground water where the background cancer risk level exceeds 1×10^{-6} (1 in 1,000,000), or a hazard index value exceeds 1.0, or other criteria defined in Section 3.0.

Accordingly, background concentrations must be determined for substances that are naturally-occurring that are contaminants of concern at the site. If pre-existing data are not available or are

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[3] *Residential land use means any property currently or proposed for use as a residence or dwelling, including a house, apartment, mobile home, nursing home or condominium; or public use area, including a school, educational center, day care center, playground, unrestricted outdoor recreational area or park.*

[4] *Non-residential land use means any property that does not exclusively meet the definition of residential land use.*

not representative of the site, then determining background concentrations is a necessary element of site characterization. A site-specific number of soil samples collected from the same soil type in an area not affected by contamination from the site and not impacted from other releases should be analyzed to characterize background soil concentrations. For ground water, data should be collected from an upgradient location to determine background concentrations of naturally occurring contaminants of concern.

Ultimately, it will be necessary to gain approval from the KDHE/BER project manager for sampling strategies meant to characterize background environmental quality. Background environmental quality data may be presented to the KDHE/BER project manager from pre-existing referenced sources of information or a sampling and statistical analysis plan for the determination of background concentrations may be submitted for approval prior to implementation. The method of drilling, constructing, developing, and sampling wells will have a significant impact on the ground water geochemistry, especially for metals.

KDHE considers the speciation of metals and other inorganics in soils when determining risk-based standards. The general definition of speciation is the molecular structure or oxidation states of a compound. For the Tier 1 and Tier 2 approach, KDHE considers the most toxic form of a naturally occurring compound to assure protectiveness. As an example, this approach is factored in the Tier 2 cleanup concentrations for chromium and cyanide listed in Appendix A. In the Tier 2 approach, KDHE assumes 100 percent of the chromium detected is hexavalent chromium (Cr^{+6}), which is significantly more toxic compared to trivalent chromium (Cr^{+3}). For cyanide, copper cyanide is the most toxic form of the cyanides, including free cyanide. For a majority of the naturally occurring compounds listed in the Tier 2 table a general risk-based value is provided for those compounds since there is insufficient toxicological data available to determine risk-based standards for the various forms of these compounds. The user of RSK Manual may opt to perform a Tier 3 analyses based upon the actual speciation of a compound detected at the site or additional toxicological data available for that compound.

After completing the site characterization and assessment of background environmental quality, if contamination is equal to or less than KDHE-approved background concentrations for the contaminants of concern, KDHE may determine that no further action is required. However, if contamination exceeds KDHE-approved background concentration, the decision should be made to remediate the site to KDHE-approved background concentrations or proceed to Tier 2 or Tier 3, as appropriate.

5.2 TIER 2

After completing site characterization, including characterization of background environmental quality, if appropriate, and determining the appropriate land use, the user must compare each contaminant's maximum concentration detected in soil and ground water to each contaminant's respective concentration in the Tier 2 Risk-Based Summary Table in Appendix A. If any contaminant of concern is detected in excess of its appropriate Tier 2 value(s), KDHE may determine that remedial action is warranted. Alternatively, a Tier 3 analyses as described in Section 5.3. may be performed. If KDHE's Tier 2 Risk-Based Summary Table does not list risk-based cleanup values for contaminants of concern detected at the property, KDHE will perform the appropriate Tier 2 calculations. Periodically, KDHE will update the Tier 2 Risk-Based Summary Table and Appendices B and C as needed.

The Tier 2 Risk-Based Summary Table has six separate concentrations for each listed contaminant. For soils, the Tier 2 Risk-Based Summary Table provides two separate human health risk-based concentrations for residential and non-residential land use settings and two separate concentrations which are protective of ground water for residential and non-residential land use settings. Chemical-specific human health risk-based concentrations represent the concentrations at which the contaminants pose the maximum acceptable human health risk as a result of carcinogenic (c) or non-carcinogenic (n) toxicity. In addition, the soil saturation concentration(s) has been calculated and, if the concentration is less than the contaminant's toxicity concentration or soil to ground water pathway concentration, the soil saturation concentration is the default cleanup value. The soil saturation concentration represents the maximum concentration that a contaminant may be present in soil, given the referenced geophysical setting and each contaminant's physical and chemical properties and suggests the presence of free phase product, which must be remedied in all cases. This approach is recommended in *Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals,* EPA/540/R-92/003, December 1991.

Tier 2 Risk-Based Summary Table ground water concentrations are derived with the assumption that the aquifer is a source of potable water. Contaminants leaching from soil to ground water may be significant. Soil contamination cleanups may frequently be determined by chemical specific soil to ground water pathway concentrations to protect ground water quality. The Tier 2 Risk-Based Summary Table provides chemical-specific human health risk-based values for residential and non-residential land use settings. It should be noted that for those contaminants for which a federal Safe Drinking Water Act maximum contaminant level (MCL) has been promulgated into law, the Tier 2 ground water value for both residential and non-residential land use settings is the chemical-specific MCL. In the event ground water is to be used as a source of drinking water the ground water cleanup concentration defaults to the residential land use concentration irrespective of land use.

For a few contaminants listed in the Tier 2 Risk-Based Summary Table, alternative methods were employed to determine chemical-specific concentrations that are protective of human health, environmentally safe, or preserve the aesthetic quality of drinking water supplies. Alternative methods include the use of the most toxic speciation of metals, the use of health advisory data in the absence of chemical-specific toxicological data, drinking water odor and taste, and the consideration of potential for explosive environments, etc. For these contaminants, the cleanup concentrations are generally more stringent than strictly human health risk-based concentrations.

5.2.1 EXPOSURE ASSESSMENT

The primary objectives of the exposure assessment are to identify potentially exposed receptors and the exposure pathways by which those receptors may be exposed to contaminants, and to measure or estimate the magnitude, duration, and frequency of exposure to environmental contamination for each receptor category. For the Tier 2 Risk-Based Summary Table, KDHE/BER divided receptors into two general categories, residents and non-residents, according to the appropriate land-use designation for each site. The significant differences between the two receptor classes include exposure frequency, exposure duration, and the consideration that children are potentially exposed at residential land-use settings and are more sensitive to environmental contaminants. The non-residential land-use setting is based upon industrial or commercial settings where adult workers are considered the potentially exposed receptor.

Human health risk-based contaminant concentrations for both residential and non-residential scenarios were calculated for soil and ground water. The soil exposure pathways evaluated in the human health risk-based calculations include incidental ingestion of soil, inhalation of airborne particulates (dusts), inhalation of chemicals volatilizing from the soil (volatile compounds only), and dermal contact with soil (organic compounds only). The reasoning for evaluating dermal contact for organics only is based upon chemical-specific absorption factors. For organics, the absorption factor is generally 1 to 30 percent; however, for non-organic contaminants, the absorption factor is generally less than 1 percent. Exposure pathways for ground water include ingestion, inhalation of chemicals volatilizing from the water (volatile compounds only), and dermal contact with water.

Default exposure factors were obtained primarily from *Risk Assessment Guidance for Superfund Supplemental Guidance Standard Default Exposure Factors* (OSWER Directive, 9285.6-03) dated March 25, 1991 and more recent information from EPA Office of Solid Waste and Emergency Response and EPA Office of Research and Development. Exposure factors used in the Tier 2 Risk-Based Summary Table are presented in Table 1 and Table 2 for ground water and soil, respectively.

For the residential land use scenario, child exposure parameters were used to evaluate non-carcinogenic risks in both soil and ground water, since child exposure parameters are more sensitive to this class of environmental contaminants. Adult exposure parameters were used to evaluate carcinogenic risks for residents because, as a result of the methodologies used to calculate risk, the exposure to adults is the most significant receptor category. Adult exposure parameters were used to evaluate both carcinogenic and non-carcinogenic risks for non-residents as they are the only receptors in a non-residential land-use setting.

Chemical-specific risk-based concentrations provided in the Tier 2 Risk-Based Summary Table combine current EPA toxicity values with "standard" exposure factors to estimate contaminant concentrations in environmental media (soil and water) that are protective of receptors, including sensitive groups (children or the elderly), over a lifetime. Chemical-specific human health risk-based concentrations were calculated for more than 150 potential contaminants, including metals, volatile organic compounds, semi-volatile organic compounds, pesticides, herbicides, and polychlorinated biphenyls (PCBs). These chemicals are listed in Appendix B with their respective chemical-specific parameters (including water solubility, Henry's Law constant, the water partition coefficient for inorganic constituents [Kd], diffusivity in air, and diffusivity in water).

5.2.2 TOXICITY ASSESSMENT

The primary objective of a toxicity assessment is to evaluate the inherent toxicity of contaminants, including each contaminant's potential carcinogenic risk and all other non-carcinogenic health risks. Toxicity assessments rely on scientific data available in literature on adverse effects in humans and non-human species to identify the critical toxicological effects.

For the purpose of developing the Tier 2 Risk-Based Summary Table, KDHE/BER used established contaminant-specific toxicity values developed and maintained by the EPA. EPA-approved toxicological data, known as reference doses (RfD) for non-carcinogens and slope factors (SF) for carcinogens, were obtained from the *Integrated Risk Information System* (IRIS) through June 2001, the *Health Effects Assessment Summary Table* (HEAST) through June 2001, EPA's National Center for Environmental Assessment (NCEA, formerly known as ECAO), or other appropriate EPA resources. The priority sequence among the referenced toxicological databases used from the most preferred to the least preferred is as follows: (1) IRIS, (2) HEAST, (3) NCEA, (4) withdrawn from IRIS or HEAST and under review, and (5) other EPA resources approved by KDHE. Contaminant toxicological data used in developing the Tier 2 Risk-Based Summary Table are provided in Appendix C.

Oral cancer slope factors ("SFo") and oral reference doses ("RfDo") were used for both oral and inhaled exposures for contaminants lacking inhalation values. Inhalation slope factors ("SFi") and inhalation reference doses ("RfDi") were used for the inhalation and exposure pathways. Route-to-route extrapolations were used when there were no toxicity values available for a given route of exposure. In these cases, oral toxicological data was used for dermal slope factors and dermal reference doses.

5.2.3 RISK CHARACTERIZATION

The final step in developing risk-based cleanup concentrations that are protective of human health is the risk characterization phase. This process integrates exposure and toxicity information to quantify contaminant-specific risk-based concentrations that are protective of human health. The risk characterization process considers the two categories of potential adverse human health effects, carcinogenic and non-carcinogenic health effects through two separate land uses, residential and non-residential. Not all contaminants are classified as carcinogens, or potential cancer-causing contaminants; however, all contaminants, including carcinogens, are evaluated based upon their respective most critical adverse health effect, whether it is the contaminant's carcinogenic toxicity or it's non-carcinogenic toxicity.

For non-carcinogens, toxicologists have determined that there is a threshold concentration below which there would be no adverse health effect to an exposed population. Toxicologists universally claim that exposure to any carcinogenic contaminant, or any carcinogenic situation, such as exposure to sunlight, cigarette smoke, etc., carries a risk of an adverse health effect, therefore human health risk is not characterized by the existence of a threshold concentration.

5.2.3.1 GROUND WATER

Tier 1 and Tier 2 evaluations assume that ground water from the impacted aquifer is potable in quantities capable of serving domestic needs. Accordingly, for those contaminants for which the federal Safe Drinking Water Act has promulgated primary maximum contaminant levels (MCLs), the Tier 1 and Tier 2 ground water cleanup concentrations are the MCLs. For all other contaminants addressed within this document, Equations 3-1 and 3-2 were used to calculate human health risk-based concentrations for ground water for both carcinogenic and non-carcinogenic contaminants. **If ground water is to be used for drinking water purposes at a non-residential site, the risk-based Tier 2 concentration defaults to the MCL or the residential land use concentration.** Exposure factors used in the equations are provided in Table 1. Contaminant chemical, physical, and toxicological data are provided in Appendices B and C.

5.2.3.2 SOILS

KDHE has identified three potential conditions which must be assessed collectively to determine the appropriate Tier 2 concentration for a contaminant in soil. The first condition is impact to human health via ingestion of contaminated soil, inhalation of volatile organic compounds and/or fugitive emission dusts, and dermal contact with contaminated soil. The second condition to be assessed is the contaminant concentration in soil which would be protective of ground water. The third condition is provided for in *Risk Assessment Guidance for Superfund: Volume 1 – Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals)*; which indicates that the soil saturation concentration for each contaminant be quantified to determine the concentration at which it could be reasonably assumed that free phase product is present. Under such a condition, KDHE would require remediation of the soils to mitigate the free phase contamination.

Equations used to calculate chemical-specific human health risk-based concentrations in soil for carcinogens and non-carcinogens are derived from referenced EPA guidance documents with the formulas presented in Equations 3-3 and 3-4, the exposure factors provided in Table 2, and contaminant chemical, physical, and toxicological data provided in Appendices B and C. For each of the two land uses, the Tier 2 Risk-Based Summary Table provides two separate soil concentration values. Under the "Soil Pathway" column, each chemical-specific concentration is based upon either the threat to human health or the soil saturation concentration, which ever is less. Each chemical-specific concentration is notated to inform the user as to which adverse health effect the Tier 2 Soil Pathway is based on. For carcinogenic risk, the notation is "*c*". For non-carcinogenic risk, the notation is "*n*". If the soil saturation concentration is used, the notation is "*s*". The appropriate Tier 2 soil cleanup concentration will be the lesser of the calculated values for acceptable impact to human health, the soil saturation concentration, or potential threat to ground water.

The methodology used to determine soil cleanup levels incorporated the additive adverse human health effects associated with the inhalation of vapors from volatile organic chemical contaminated soil. EPA toxicity data indicate that risks posed from exposure to certain contaminants in soil via the inhalation pathway far outweigh the risks posed via ingestion;

therefore, the human health risk-based concentrations have been calculated to address this pathway as well. For the purposes of this document, volatile organic chemicals (VOCs) are those chemicals having a Henry's Law constant greater than 1×10^{-5} atmospheres per cubic meter per mole (atm-m3/mol) and a molecular weight less than 200 grams/mole. These contaminants are evaluated for potential volatilization from soil or water to air using volatilization factors which are identified in Appendix B under the column "Volatization Factor" (VF). To calculate inhalation exposure risk, each contaminant's volatilization factor must first be calculated. For volatilization from water to air the volatilization factor is assumed to be 0.5 liters per cubic meter (L/m^3) based upon studies by Andelman 1990. The soil-to-air VF is used to define the relationship between the concentration of the contaminant in soil and the flux of the volatilized contaminant to air. The VF equation (Equation 5-1) represents a dispersion model that simulates the dispersion of contaminants in the atmosphere.

The soil saturation concentration corresponds to the contaminant concentration in soil at which the absorptive limits of the soil particles, the solubility limits of the soil pore water, and saturation of soil pore air have been reached. Above this concentration, the contaminant may be present as a pure liquid phase for contaminants that are liquid at ambient soil temperatures and pure solid phase for compounds that are solid at ambient soil temperatures.

A soil saturation concentration has been calculated using Equation 5-2 for all organic compounds. The soil saturation concentration represents chemical-physical limits of a soil matrix as defined by the parameters provided in Equation 5-2. Since these values represent the concentration at which soil pore air is saturated with a chemical, volatile emissions reach their maximum at the soil saturation value. If the chemical-specific soil saturation concentration is less than its corresponding human health risk-based concentration, the soil saturation concentration is used as the default soil concentration Tier 2 cleanup level.

5.2.3.3 SOIL TO GROUND WATER PROTECTION

The methodology for calculating soil concentrations protective to prevent the migration of soil contaminants to ground water was derived from the document titled, "*Soil Screening Guidance: Technical Background Document*", OSWER 9355.4-17A, EPA/540/R-95/128 May 1996. KDHE utilized the EPA methodology for two basic reasons. The "*Soil Screening Guidance*" document is EPA supported and extensively peer-reviewed, and the methodology presented therein is relatively simple.

Migration of a contaminant from soil to ground water can be envisioned as a two-stage process: (1) release of the contaminant in soil leachate and (2) transport of the contaminant soil leachate through the underlying soil to the aquifer and, potentially, to a receptor well. For the purposes of this document, KDHE's Tier 2 Risk-Based Summary Table assumes the receptor well to be at the source area; therefore, fate and transport modeling is not an element of the Tier 2 Risk-Based Summary Table. KDHE has adopted EPA's screening dilution factor of 20 for calculating chemical-specific soil-to-ground water pathway concentrations.

Equation 5-3 is the soil-water partition equation used to calculate the concentration of a contaminant in soil above which a threat of the contaminant entering the ground water is a concern. Tier 2 soil-to-ground water pathway concentrations are back-calculated from acceptable ground water concentrations (MCLs or human health risk-based concentrations determined using equations 3-1 and 3-2. The acceptable ground water concentration is multiplied by the dilution factor of 20 to obtain a target leachate concentration.

Although simplified, the methodology described in this section is theoretically and operationally consistent with investigation and modeling efforts that are conducted to develop soil cleanup goals and cleanup levels for protection of ground water at Superfund sites. Simplifying assumptions for the migration to ground water pathway include:

- The source is infinite (i.e:, steady-state concentrations will be maintained in ground water over the exposure period);
- Contaminants are uniformly distributed throughout the zone of contamination;
- Soil contamination extends from the surface to the ground water table (i.e., adsorption sites are filled in the unsaturated zone beneath the area of contamination);
- There is no chemical or biological degradation in the unsaturated zone;
- Equilibrium soil/water partitioning is instantaneous and linear in the contaminated soil;
- The receptor well is at the source area (i.e., there is no dilution from recharge down-gradient of the property and the well is screened within the plume);
- The aquifer is unconsolidated and unconfined (surficial);
- Aquifer properties are homogenous and isotropic;
- There is no attenuation (i.e., adsorption or degradation) of contaminants in the aquifer; and,
- The contaminant does not exist as free product in the soil at the property.

5.3 TIER 3

Tier 3 offers the user the opportunity to determine site-specific risk-based contaminant concentrations that are protective of human health and the environment. Tier 3 involves a substantial increase in effort relative to Tier 1 and Tier 2, including the collection of additional site-specific geophysical data, such as vertical profiling fraction organic carbon, bulk density, aquifer characterization, and/or performing more sophisticated contaminant fate and transport models. If the user opts to perform a Tier 3 evaluation, it must be done with KDHE/BER oversight, including the submittal of appropriate work plans to perform any necessary additional work. KDHE will not authorize the performance of a Tier 3 analysis for contaminants of concern that are regulated by federal, state or local laws, such as federal Safe Drinking Water Act which mandates MCLs for drinking water aquifers.

Performing a Tier 3 analysis will require the collection of significantly more information than that required by either Tier 1 or Tier 2. Tier 3 risk-based concentrations (RBCs) will be based on

KDHE-approved predicted and validated contaminant fate and transport estimates of the contaminants of concern potential to migrate away from source areas. Tier 3 analysis will allow monitoring points of compliance to be installed away from the source area in order to verify the ongoing effectiveness of facilitated natural attenuation and biodegradation; however, such monitoring points of compliance cannot extend beyond the property boundaries without department approval. A Tier 3 sampling and analysis plan may be required beyond that required by either the Tier 1 or Tier 2 analysis. Default assumption parameters that were employed by KDHE to calculate human health risk-based cleanup goals are included in Equations 5-1 and 5-2, and Table 3. Parameters for which site-specific data may be substituted to perform a Tier 3 analysis are denoted with an asterisk. The following is a list of additional data, which may be necessary to complete a Tier 3 analysis:

- Additional geological, geophysical or hydrological data, including items such as unsaturated zone physical and geological properties (vertical distribution profiling fraction organic carbon, bulk density, total porosity, air-filled porosity, water-filled porosity, etc.), thickness of unsaturated zone, thickness of the saturated aquifer, aquifer transmissivity, hydraulic conductivity, gradient, infiltration rate, and longitudinal, lateral, and vertical dispersivities;
- Documented property ownership boundaries, current and likely future land use designations, target receptors within the area, and implementability of potential institutional controls; and,
- Any additional data necessary to perform a sophisticated contaminant fate and transport model, i.e., contaminant mass limit models, contaminant degradation rates, fraction of vegetative cover, three-dimensional source area characterization, mean wind speed, infiltration rate, etc.

A common Tier 3 analysis could be the implementation of a sophisticated contaminant fate and transport model. Any model used for a Tier 3 analysis must be approved by the department project manager and must be a public domain model. In the event a proprietary model or any other model that KDHE does not possess is used in a Tier 3 analysis, the department may request a copy of the model for review and approval. The following are examples of measures that may be undertaken as part of a Tier 3 analysis:

- The use of property-specific numerical soil or ground water modeling to predict the effect of contaminant fate and transport mechanisms, including heterogeneous geological conditions;
- Characterization of property sources and exposure pathways by using property assessment data to identify relevant sources, transport mechanisms, impacted media, and exposure pathways;
- For pesticides, standard application rates have not been documented. Accordingly, the user may perform research to determine appropriate pesticide-specific standard application rates as a Tier 3 risk analysis activity.
- Identification of all potential receptors. Actual or potential receptors should be differentiated based on current and likely future land use, and upon the ability to place institutional controls at the property to eliminate potential exposure pathways;

- An evaluation of potential remedial actions that would reduce the human health or environmental risk to acceptable levels; and,
- Determination of site-specific cleanup goals based upon site-specific data, which may result in less stringent site-specific cleanup goals.

In the event a site-specific Tier 3 analysis determines that Tier 2 cleanup goals are not protective of human health or the environment, the more stringent Tier 3 cleanup goals will be the site-specific cleanup goals for the site.

6.0 TOTAL PETROLEUM HYDROCARBONS

Total petroleum hydrocarbons (TPH), for the purpose of this section of the RSK Manual includes all undifferentiated hydrocarbons including carbon range compounds C^{5} through C^{35} containing various percentages of straight chain alkanes, branched chain alkanes, cycloalkanes, straight chain alkenes, branched chain alkenes, cycloalkenes, alkyl benzenes, naphtheno benzenes, alkyl naphthalenes and polynuclear aromatics. TPH cleanup concentrations in soil and ground water, as related to Tier 2 of this RSK Manual, shall be quantified by summing TPH using EPA SW-846 modified method 8015, also known as laboratory analytical methods OA1 for gasoline range organics (GRO) and OA2 for diesel range organics (DRO).

The use of Tier 2 values for TPH-GRO and TPH-DRO shall be used in conjunction with the values for individual constituents in order to determine site cleanup goals. These constituents include but are not limited to benzene, toluene, ethylbenzene, total xylenes (BTEX), methyl-tert-butyl-ether (MTBE), ethylene dibromide (EDB), and 1,2-dichloroethane (1,2-DCA) for TPH-GRO and chrysene, pyrene, benzo[a]pyrene, and anthracene for TPH-DRO. Please note that when a Tier 2 value is less than the method detection limit, the method detection limit becomes the Tier 2 value.

Considering that TPH detected at a site is commonly found as either GRO or DRO, KDHE has developed two separate Tier 2 risk-based concentrations based upon whether the TPH is entirely GRO or DRO. For pure GRO-type TPH, the Tier 2 cleanup concentrations are based upon the physical, chemical and toxicological properties of n-hexane. For pure DRO-type TPH, the Tier 2 cleanup concentrations are based upon the physical, chemical and toxicological properties of pyrene.

If the site has only one type of TPH (GRO or DRO), the risk-based cleanup concentrations are based upon their petroleum type as provided in Tier 2 of the RSK Manual. For sites where both types of TPH are detected, the sum of the ratios of each hydrocarbon type must be calculated as follows:

$$\frac{X}{\text{GRO Tier 2 Value}} + \frac{Y}{\text{DRO Tier 2 Value}} = N$$

Where:

X = Detected GRO Concentration

Y = Detected DRO Concentration

N = Sum

For instance, where GRO and DRO are detected at 22 mg/kg and 1,000 mg/kg respectively, the hazard index would be determined as N = (22/220) + (1,000/2,000). Accordingly N = 0.6, which is less than 1.0, therefore this scenario would be acceptable. Any N value greater than 1.0 would be considered an excessive risk and may require corrective action as determined by the BER project manager.

Non-residential TPH standards should not be used in the following situations unless approved by the KDHE project manager:

1) sites where contamination is caused by a responsible party that does not own or control the property;
2) sites where a deed restriction can not be used to control future use of the property (i.e. assuring that the non-residential setting in the future); and
3) sites where contamination is located on the responsible party's property but is migrating or threatening to migrate to an adjacent property not under the ownership or control of the responsible party.

The current and future use of the property and the ownership of the property must be considered when determining the use of "Non-Residential" TPH Tier 2 levels. In most cases, the residential standards should be used as the target clean-up levels.

Independent of the TPH Tier 2 levels presented in Appendix A of this RSK Manual, all free product, including hydrocarbon saturated soil, must be addressed. KDHE has calculated soil saturation values for TPH GRO and TPH DRO of 3,300 mg/kg and 70,000 mg/kg, respectively, using the methodology described above in Section 5.2.3.2. These values are estimates, and site-specific soil saturation values can vary based upon the nature of the product released at each site. However, these soil saturation values provide a default when a site-specific soil saturation value has not been calculated.

KDHE considers any apparent product on the ground water surface to be a likely indicator of soil saturation, and therefore an indicator of the need to further evaluate the potential for free product and possible remediation at the site.

7.0 NITRATE AND AMMONIA

KDHE/BER has a policy, BER-RS-12 titled "Cleanup Levels for Nitrate," originally developed in 1991, which addresses soil and ground water contaminated by nitrate. Policy BER-RS-12 has been recently revised through discussions with agronomy experts at Kansas State University and those revisions are reflected in this version of the RSK Manual.

Soil Pathway:

- In areas where no vegetation is present (i.e., contamination in a gravel roadway, parking area, etc.) the following RSK standards apply:

  Upper 8 inches of soil - 85 mg/kg total nitrate plus ammonia (N);

  Below 8 inches in depth - 40 mg/kg nitrate plus ammonia (N).

- In areas where vegetation is present (i.e, cultivated and cropped agricultural ground, pasture, lawn, etc.) the following RSK standards apply:

  Upper 24 inches of soil - 200 mg/kg total nitrate plus ammonia (N), or the maximum application rate recommended by Kansas State University for the particular crop;

  Below 24 inches in depth - 40 mg/kg nitrate plus ammonia (N).

Ground Water Pathway:

> The MCL for nitrate is 10 mg/l, measured as nitrogen; or 45 mg/l when measured as nitrate.
>
> KDHE/BER will consider monitoring options for nitrate concentrations between 10 mg/l and 20 mg/l. This strategy for monitoring follows the agency's "Kansas Nitrate Strategy" document approved by USEPA in 1997.

KDHE/BER will also consider the following site-specific conditions when determining the appropriate response action for a site contaminated by nitrate and/or ammonia.

1) If it is not possible to excavate soil to reach a 40 mg/kg total nitrate plus ammonia (N) level then the responsible party must determine the vertical extent of total nitrate plus ammonia (N) contamination through vertical profiling approved by KDHE.

2) If ground water is 50 feet or less in depth then ground water monitoring wells may be requested by KDHE in the area of contamination and hydraulically down gradient to the nitrate concentration in ground water additional actions may be required:

a) If nitrate (N) in ground water is between the drinking water standard of 10mg/l and KDHE Bureau of Water's policy for public water supply wells of 20 mg/l, then the responsible party may be requested by KDHE to monitor the situation over a period of time. Note that where nitrate is detected at concentrations in excess of 10mg/l in actual private or public water supply wells, other requirements may apply as specified by the KDHE Bureau of Water "Kansas Nitrate Strategy."

b) If nitrate (N) in groundwater exceeds 20 mg/l then the responsible party may be required by KDHE to install a remedial system to hydraulically contain and/or remove the contamination.

c) If nitrate (N) in ground water is below the drinking water standard, or if the nitrate is shown to be from off-site sources, the monitoring points must be sampled in accordance with KDHE identified sites reclassification criteria to monitor ground water quality.

3) If ground water depth exceeds 50 feet, the need for installation of monitoring wells will be determined by KDHE on a case by case basis depending on ground water usage, soil type, and soil concentration of nitrate plus ammonia (N). Depending on nitrate concentrations in ground water, additional actions as described above may be required.

4) If vertical soil profiling indicates the presence of impervious bedrock (i.e. shale) isolating the nitrate/ammonia from ground water, up to 200 mg/kg nitrate plus ammonia (N) can be left in place (as determined by the KDHE project manager).

Excavation is commonly implemented as an appropriate response action to address soil contaminated with nitrate and/or ammonia. Nitrate and ammonia contaminated soil can be land applied on cultivated land at approved application rates. This approach requires the completion of the KDHE Land Application Work Plan and Agreement Form available from the KDHE project manager.

8.0 TABLES, FORMULAS, AND EQUATIONS

TABLE 1

GROUND WATER EXPOSURE FACTORS

ID	Description	Residents	Non-Residents
TR	Target cancer risk	1E-06, 1E-05, 1E-04	1E-06, 1E-05, 1E-04
THI	Target hazard index	1	1
BW	Body weight (kg)		
Bwa	Adult	70	70
BWc	Child (0-6 years)	15	NA
Irw	Daily water ingestion rate (L/day)		
Irwa	Adult	2	1
Irwc	Child	1	NA
INH	Inhalation rate (m3/day)		
INHa	Adult	20	20
INHc	Child	10	NA
VFw	Volatilization Factor (L/m3)	0.5	0.5
CF	Conversion Factor (L/cm3)	0.001	0.001
SA	Skin Surface Area (cm2)		
Saa	Adult	20,000	20,000
Sac	Child	7,000	NA
Kp	Permeability coefficient (cm/hr)	Chemical-specific	Chemical-specific
ET	Exposure Time (hours/day)	1	0.5
EF	Exposure Frequency (days/year)	350	250
ED	Exposure Duration (years)		
Edca	Cancer (adult)	30	25
Ednca	Noncancer (adult)	NA	25
Ednec	Noncancer (Child)	6	NA
AT	Averaging Time		
ATca	Cancer (adult)	70	70
Atnca	Noncancer (adult)	NA	25
Atncc	Noncancer (child)	6	NA
SF	Slope Factor (carcinogens)	Chemical-specific	Chemical-specific
RfD	Reference Dose	Chemical-specific	Chemical-specific

Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A) EPA, 1991 Human Health Evaluation Manual, Supplemental Guidance "Standard Default Exposure Factors".

Risk Assessment Guidance for Superfund, Part B: Development of Risk-based Preliminary Remediation Goals.

EQUATION 3-10

GROUND WATER / CARCINOGENS

$$\text{RBC (mg/L)} = \frac{\text{TR} \times \text{BW} \times \text{AT} \times 365 \text{ days / year}}{\text{EF} \times \text{ED} \left[(\text{IR}_w \times \text{SF}_o) + (\text{VF}_w \times \text{Inh} \times \text{SF}_i) + (\text{ET} \times \text{CF} \times \text{SA} \times \text{Kp} \times \text{SF}_o)\right]}$$

EQUATION 3-2

GROUND WATER / NON-CARCINOGENS

$$\text{RBC (mg/l)} = \frac{\text{THI} \times \text{BW} \times \text{AT} \times 365 \text{ days / year}}{\text{EF} \times \text{ED} \times \left[(\text{IR}_w \times 1/\text{RfD}_o) + (\text{VF}_w \times \text{Inh} \times 1/\text{RfD}_i) + (\text{ET} \times \text{CF} \times \text{SA} \times \text{Kp} \times 1/\text{RfD}_o)\right]}$$

TABLE 2

SOIL EXPOSURE FACTORS

ID	Description	Residents	Non-Residents
TR	**Target cancer risk**	**1E-06, 1E-05, 1E-04**	**1E-06, 1E-05, 1E-04**
THI	**Target hazard index**	**1**	**1**
BW	**Body weight (kg)**		
Bwa	**Adult**	**70**	**70**
BWc	**Child (0-6 years)**	**15**	**NA**
INGs	**Soil ingestion rate (mg/day)**		
INGsa	**Adult**	**100**	**50**
INGsc	**Child**	**200**	**NA**
INH	**Soil inhalation rate (m3/day)**		
INHa	**Adult**	**20**	**20**
INHc	**Child**	**10**	**NA**
VFs	**Soil Volatilization Factor (m3/kg)**	**Chemical-specific**	**Chemical-specific**
CF	**Conversion Factor (kg/mg)**	**1E-06**	**1E-06**
PEF	**Particulate Emission Factor (m3/kg)**	**1.18E+09**	**1.18E+09**
SA	**Skin Surface Area (cm2/day)**		
Saa	**Adult**	**5000**	**5000**
Sac	**Child**	**1750**	**NA**
ABS	**Absorption Factor (fraction)**	**0.1**	**0.1**
AF	**Adherence Factor (mg/cm2)**	**0.2**	**0.2**
EF	**Exposure Frequency (days/year)**	**350**	**250**
ED	**Exposure Duration (years)**		
Edca	**Cancer (adult)**	**30**	**25**
Ednca	**Noncancer (adult)**	**NA**	**25**
Ednec	**Noncancer (child)**	**6**	**NA**
AT	**Averaging Time**		
Atca	**Cancer (adult)**	**70**	**70**
Atnca	**Noncancer (adult)**	**NA**	**25**
Atncc	**Noncancer (child)**	**6**	**NA**
SF	**Slope Factor (carcinogens)**	**Chemical-specific**	**Chemical-specific**
RfD	**Reference Dose**	**Chemical-specific**	**Chemical-specific**

See references in Table 1

EQUATION 3-3

SOIL / CARCINOGENS

$$\text{RBC (mg/kg)} = \frac{\text{TR} \times \text{BW} \times \text{AT} \times 365\ \text{days / year}}{\text{EF} \times \text{ED}\,[(\text{ING}_s \times \text{CF} \times \text{SF}_o) + (\text{INH} \times \text{SF}_i \times \{1/\text{VF}_s + 1/\text{PEF}\}) + (\text{SF}_o \times \text{CF} \times \text{SA} \times \text{AF} \times \text{ABS})]}$$

EQUATION 3-4

SOIL / NON-CARCINOGENS

$$\text{RBC (mg/kg)} = \frac{\text{THI} \times \text{BW} \times \text{AT} \times 365\ \text{days / year}}{\text{EF} \times \text{ED} \times [(\text{ING}_s \times \text{CF} \times 1/\text{RfD}_o) + (1/\text{RfD}_i \times \text{INH} \times \{1/\text{VF}_s + 1/\text{PEF}\}) + (1/\text{RfD}_o \times \text{CF} \times \text{SA} \times \text{AF} \times \text{ABS})]}$$

EQUATION 5-1 VOLATILIZATION FACTOR EQUATION AND PARAMETERS

$$\mathrm{VF}\ (\mathrm{m}^3/\mathrm{kg}) = \frac{\mathrm{Q}}{\mathrm{C}} * \frac{[(3.14)(D_\mathrm{A})(\mathrm{T})]^{1/2}}{2 \mathrm{x}\ \rho_\mathrm{b} x D_A} \mathrm{x}10^{-4} (m^2/cm^2)$$

$$\text{where } D_\mathrm{A} = \frac{[(\theta_a^{10/3} D_i H' + \theta_w^{10/3} D_w)/n^2]}{\rho_\mathrm{b} K_d + \theta_\mathrm{w} + \theta_a H'}$$

Chemical-Specific Parameters	**Default**
VF = Volatilization factor (m^3/kg)	--
D_A = Apparent diffusivity (cm^2/s)	--
Q/C = Inverse of the mean concentration at the center of square source (g/m^2-s per kg/m^3)	81.64
T = Exposure interval (seconds)	
Residential	9.5 E+08
Non-residential	7.9 E+08
ρ_b = Dry soil bulk density (g/cm^3)	1.5 *
θ_a= Air filled soil porosity (Lair/Lsoil)	0.28 *
N = Total soil porosity (Lpore/Lsoil)	0.43 *
θ_w= Water filled soil porosity (Lwater/Lsoil)	0.15 *
ρ_s = Soil particle density (g/cm^3)	2.65 *
Di = Diffusivity in air (cm^2/s)	Chemical-specific
RG = Universal Gas Constant (atm-m3/mole-K)	0.000082
TEMP = Temperature (K)	293
H = Henry's Law constant (atm-m^3/mol)	Chemical-specific
H' = Dimensionless Henry's Law constant	H/(RG x TEMP)
D_w = Diffusivity in water (cm^2/s)	Chemical-specific
Kd = Soil-water partition coefficient (cm3/g) = Kocfoc	Chemical-specific
Koc = Soil organic carbon-water partition coefficient (cm3/g)	Chemical-specific
Foc = Fraction organic carbon in soil (g/g)	0.01 *

* *Asterisk notes the chemical-specific parameters that may be modified in a property-specific Tier 3 analyses.*

EQUATION 5-2 SOIL SATURATION EQUATION AND PARAMETERS

$$C_{sat} = \frac{S}{P_b}\ (K_d\ P_b + \theta_w + H'\theta_a)$$

Parameter Definition (units)	Default
Csat = Soil saturation concentration (mg/kg)	--
S = Solubility in water (mg/L-water)	chemical-specific
ρb = Dry soil bulk density (kg/L)	1.5 *
Kd = Soil-water partition coefficient (L/kg)	Koc × foc (chemical-specific)
Koc = Soil organic carbon/water partition coefficient (L/kg)	chemical-specific
foc = Fraction organic carbon in soil (g/g)	0.01 *
θw = Water-filled soil porosity (Lwater/Lsoil)	0.15 *
H' = Dimensionless Henry's law constant	Chemical-specific
θa = Air-filled soil porosity (Lair/Lsoil)	0.28 *
n = Total soil porosity (Lpore/Lsoil)	0.43 *
ρs = Soil particle density (kg/L)	2.65 *

* *Asterisk notes the physical and chemical-specific parameters that may be modified in a property-specific Tier 3 analysis.*

EQUATION 5-3 SOIL TO GROUND WATER MIGRATION PATHWAY EQUATION

$$C_t = C_w \left\langle (K_d) + \frac{\theta_w + \theta_a H'}{\rho_b} \right\rangle$$

TABLE 3 GROUND WATER PROTECTION PARAMETERS

Parameter Definition (units)	**Default**
Ct = Screening level in soil (mg/kg)	--
Cw = Target soil leachate concentration (mg/l)	(non-zero MCLG, MCL, or RBC) x 20 DAF
Koc = Soil organic carbon/water partition coefficient (l/kg)	Chemical-specific (see Appendix B)
foc = Fraction organic carbon in soil (g/g)	0.01 *
Kd = Soil-water partition coefficient (L/kg)	Chemical specific for inorganic contaminants; Koc × foc for organic contaminants
θw = Water-filled soil porosity (Lwater/Lsoil)	0.30 *
θa = Air-filled soil porosity (Lair/Lsoil)	0.13 *
n = Total soil porosity (Lpore/Lsoil)	0.43 *
ρb = Dry soil bulk density (kg/L)	1.5 *
ρs = Soil particle density (kg/L)	2.65 *
RG = Universal gas constant (atm-m3/mole-K)	0.000082
TEMP = Temperature (K)	293
H' = Dimensionless Henry's Law constant	H/(RG x TEMP)
H = Henry's Law constant (atm-m3/mol)	Chemical-specific (see Appendix B)

* *Asterisk notes the physical and chemical-specific parameters that may be modified in a property-specific Tier 3 analysis.*

9.0 REFERENCES

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APPENDIX A
KDHE TIER 2 RISK-BASED SUMMARY TABLE

		RESIDENTIAL SCENARIOS			NON-RESIDENTIAL SCENARIOS		
Chemical Name	**CAS No.**	**Soil Pathway**	**Soil to Ground Water Protection Pathway**	**Ground Water Pathway**	**Soil Pathway**	**Soil to Ground Water Protection Pathway**	**Ground Water Pathway**
		(mg/kg)	**(mg/kg)**	**(mg/L)**	**(mg/kg)**	**(mg/kg)**	**(mg/L)**
Acenaphthene	83-32-9	300 s	190	0.13 n	300 s	300 s	0.49 n
Acetone	67-64-1	1700 n	1.1	0.26 n	6200 n	3.8	0.93 n
Acetophenone	98-86-2	0.50 n	0.0002	0.00002 n	1.6 n	0.0006	0.00006 n
Acrolein	107-02-8	1200 n	1.3	0.31 n	9800 n	8.6	2.0 n
Acrylamide	79-06-1	1.9 c	0.0008	0.0002 c	4.2 c	0.003	0.0006 c
Acrylonitrile	107-13-1	12 c	0.002	0.0005 c	25 c	0.004	0.001 c
Alachlor (Lasso)	15972-60-8	110 c	0.08	0.002 m	240 c	0.08	0.002 m
Aldicarb (Temik)	116-06-3	67 n	0.05	0.007 m	680 n	0.05	0.007 m
Aldrin	309-00-2	0.50 c	24	5E-05 c	1.1 c	81	0.0002 c
Anthracene	120-12-7	13 s	13 s	0.62 n	13 s	13 s	2.3 n
Antimony and compounds	7440-36-0	31 n	N/A	0.006 m	820 n	N/A	0.006 m
Arsenic	7440-38-2	11 c	5.84	0.01 m	38 c	5.84	0.01 m
Atrazine	1912-24-9	38 c	0.26	0.003 m	86 c	0.26	0.003 m
Barium	7440-39-3	5500 n	N/A	2.0 m	140000 n	N/A	2.0 m
Benzene	71-43-2	9.8 n	0.08	0.005 m	17 c	0.08	0.005 m
Benzidine	92-87-5	0.04 c	5.E-05	4E-06 c	0.08 c	0.0002	1E-05 c
Benzo(a)anthracene	56-55-3	12 c	10	0.0001 c	26 c	35	0.0004 c
Benzo(b)fluoranthene	205-99-2	12 c	19 s	9.E-05 c	19 s	19 s	0.0003 c
Benzo(k)fluoranthene	207-08-9	10 s	10 s	0.001 c	10 s	10 s	0.003 c
Benzo(a)pyrene	50-32-8	1.2 c	16 s	0.0002 m	2.6 c	16 s	0.0002 m
Benzyl Chloride	100-44-7	6.4 c	0.02	0.0008 c	10 c	0.03	0.002 c
Beryllium	7440-41-7	160 n	N/A	0.004 m	4100 n	N/A	0.004 m
Bis(2-chloroethyl)ether	111-44-4	2.3 c	0.0009	0.0001 c	3.9 c	0.002	0.0002 c
Bis(2-chloroisopropyl)ether	39638-32-9	47 c	0.25	0.003 c	82 c	0.49	0.007 c
Bis(chloromethyl)ether	542-88-1	0.004 c	4.E-06	7.E-07 c	0.006 c	7.E-06	1.E-06 c
Bis(2-ethylhexyl)phthalate	117-81-7	600 c	51000 s	400 m	1400 c	51000 s	400 m
Bromacil	314-40-9	294 s	16.2	1.56 n	294 s	105	10.12 n
Bromodichloromethane	75-27-4	14 c	1.5	0.1 m	23 c	1.5	0.1 m
Bromoform	75-25-2	1100 c	2.1	0.1 m	2400 c	2.1	0.1 m
Bromomethane	74-83-9	4.8 n	0.02	0.004 n	15 n	0.09	0.01 n
1,3-Butadiene	106-99-0	0.14 c	0.004	0.0001 c	0.21 c	0.007	0.0003 c

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		(mg/kg)	**(mg/kg)**	**(mg/L)**	**(mg/kg)**	**(mg/kg)**	**(mg/L)**
n-Butylbenzene	104-51-8	140 n	8	0.021	395 s	12	0.08 n
sec-Butylbenzene	135-98-8	110 n	8	0.02 n	380 n	9	0.08 n
Butyl Benzyl Phthalate	85-68-7	1500 s	1500 s	2.1 n	1500 s	1500 s	12 n
Cadmium	7440-43-9	39 n	N/A	0.005 m	1000 n	N/A	0.005 m
Captan	133-06-2	8.8 s	8.8 s	0.24 c	8.8 s	8.8 s	0.81 c
Carbaryl (Sevin)	63-25-2	230 s	69	1.5 n	230 s	230 s	9.7 n
Carbazole	86-74-8	250 s	16	0.02 c	250 s	54	0.08 c
Carbofuran (Furadan)	1563-66-2	150 s	0.47	0.04 m	150 s	0.47	0.04 m
Carbon Disulfide	75-15-0	460 n	0.14	0.009 n	950 s	0.45	0.03 n
Carbon Tetrachloride	56-23-5	2.5 n	0.20	0.005 m	7.0 c	0.20	0.005 m
Chlordane	57-74-9	24 c	48	0.002 m	55 c	48	0.002 m
Chlorobenzene	108-90-7	78 n	4.8	0.1 m	240 n	4.8	0.1 m
Chloroform	67-66-3	3.9 c	1.2	0.1 m	6.0 c	1.2	0.1 m
Chloromethane	74-87-3	86 c	0.11	0.02 c	140 c	0.22	0.04 c
Chlorpyrifos (Lorsban/Dursban)	2921-88-2	200 n	1100	0.04 n	1700 s	1700 s	0.21 n
Chromium (total)	18540-29-9	390 n	N/A	0.1 m	4000 c	N/A	0.1 m
Chrysene	218-01-9	6.4 s	6.4 s	0.01 c	6.4 s	6.4 s	0.04 c
Copper	7440-50-8	2900 n	N/A	1.3 m	76000 n	N/A	1.3 m
Cyanazine (Bladex)	21725-46-2	10 c	0.03	0.001 c	23 c	0.11	0.003 c
Cyanide (free)	57-12-5	1600 n	N/A	0.2 m	41000 n	N/A	0.2 m
Dacthal	1861-32-1	28 s	N/A	0.11 n	28 s	2.6	0.64 n
DDD	72-54-8	35 c	190	0.0009 c	79 c	620	0.003 c
DDE	72-55-9	25 c	650	0.0007 c	56 c	2200	0.002 c
DDT	50-29-3	25 c	250	0.0005 c	56 c	660 s	0.002 c
Diazinon	333-41-5	60 n	54000 s	0.01 n	610 n	54000 s	0.08 n
Dibenzo(a,h)anthracene	53-70-3	1.2 c	3.1	4.E-06 c	2.6 c	11	1.E-05 c
Dibenzofuran	132-64-9	252 n	27	0.01 n	1351 s	86.5	0.032 n
1,4-Dibromobenzene	106-37-6	670 n	3700	0.13 n	6800 n	11000 s	0.76 n
Dibromochloromethane	124-48-1	100 c	1.7	0.1 m	230 c	1.7	0.1 m
1,2-Dichlorobenzene	95-50-1	990 s	77	0.6 m	990 s	77	0.6 m
1,4-Dichlorobenzene	106-46-7	57 c	9.5	0.075 m	92 c	9.5	0.075 m

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		(mg/kg)	(mg/kg)	(mg/L)	(mg/kg)	(mg/kg)	(mg/L)
Dichlorodifluoromethane	75-71-8	98 n	7.0	0.17 n	290 n	23	0.57 n
1,1-Dichloroethane	75-34-3	660 n	3.7	0.34 n	2100 s	13	1.3 n
1,2-Dichloroethane	107-06-2	4.7 c	0.04	0.005 m	7.3 c	0.04	0.005 m
1,1-Dichloroethene	75-35-4	0.90 c	0.12	0.007 m	1.4 c	0.12	0.007 m
1,2-Dichloroethene (cis)	156-59-2	57 n	0.80	0.07 m	180 n	0.80	0.07 m
1,2-Dichloroethene (trans)	156-60-5	94 n	1.5	0.1 m	290 n	1.5	0.1 m
2,4-Dichlorophenol	120-83-2	200 n	8.8	0.04 n	2000 n	54	0.25 n
2,4-Dichlorophenoxyacetic acid (2,4-D)	94-75-7	670 n	6.6	0.07 m	3100 s	6.6	0.07 m
1,2-Dichloropropane	78-87-5	6.0 c	0.06	0.005 m	9.3 c	0.06	0.005 m
1,3-Dichloropropene	542-75-6	1.6 c	0.01	0.001 c	2.5 c	0.03	0.002 c
Dichlorvos	62-73-7	29 c	0.03	0.003 c	66 c	0.09	0.01 c
Dieldrin	60-57-1	0.53 c	0.20	5.E-05 c	1.2 c	0.66	0.0002 c
Diethyl Phthalate	84-66-2	3200 s	740	12 n	3200 s	3200 s	78 n
2,4-Dimethylphenol	105-67-9	1300 n	13	0.28 n	14000 n	81	1.8 n
2,4-Dinitrophenol	51-28-5	130 n	0.33	0.03 n	1200 s	2.1	0.20 n
2,4-Dinitrotoluene	121-14-2	13 c	0.03	0.001 c	28 c	0.09	0.004 c
2,6-Dinitrotoluene	606-20-2	13 c	0.02	0.001 c	28 c	0.07	0.004 c
Di-n-octyl Phthalate	117-84-0	1300 n	17000 s	0.002 n	14000 n	17000 s	0.008 n
1,4-Dioxane	123-91-1	770 c	0.32	0.08 c	1700 c	1.1	0.26 c
Diuron	330-54-1	133 n	3.08	0.031 n	205 s	18.99	0.191 n
Endosulfan	115-29-7	11 s	11 s	0.09 n	11 s	11 s	0.59 n
Endrin	72-20-8	20 n	4.9	0.002 m	30 s	4.9	0.002 m
EPTC (Ethyl-dithiopropylcarbamate, s-)	759-94-4	1700 n	97	0.33 n	5300 s	590	2.0 n
Ethylbenzene	100-41-4	650 s	55	0.7 m	650 s	55	0.7 m
Ethylene dibromide	106-93-4	0.09 c	0.0006	5.E-05 m	0.20 c	0.0006	5.E-05 m
Fluoranthene	206-44-0	220 s	220 s	0.18 n	220 s	220 s	0.89 n
Fluorene	86-73-7	270 s	200	0.07 n	270 s	270 s	0.28 n
Fonofos (Dyfonate)	944-22-9	130 n	9.6	0.02 n	250 s	57	0.15 n
Formaldehyde	50-00-0	10000 n	13	3.0 n	60000 s	84	20 n
Furan	110-00-9	3.2 n	0.02	0.003 n	9.9 n	0.08	0.009 n
Glyphosate (Roundup)	1071-83-6	6700 n	300	0.7 m	68000 n	300	0.7 m

APPENDIX A
KDHE TIER 2 RISK-BASED SUMMARY TABLE

		RESIDENTIAL SCENARIOS			NON-RESIDENTIAL SCENARIOS		
Chemical Name	CAS No.	Soil Pathway	Soil to Ground Water Protection Pathway	Ground Water Pathway	Soil Pathway	Soil to Ground Water Protection Pathway	Ground Water Pathway
		(mg/kg)	(mg/kg)	(mg/L)	(mg/kg)	(mg/kg)	(mg/L)
Heptachlor	76-44-8	1.9 c	110	0.0004 m	4.2 c	110	0.0004 m
Heptachlor Epoxide	1024-57-3	0.87 n	3.3	0.0002 m	2.1 c	3.3	0.0002 m
Hexachlorobenzene	118-74-1	5.3 c	11	0.001 m	12 c	11	0.001 m
Hexachlorobutadiene	87-68-3	13 n	18	0.002 n	140 n	100	0.009 n
Hexachloroethane	67-72-1	67 n	4.3	0.01 n	680 n	26	0.07 n
n-Hexane	110-54-3	220 s	39	0.11 n	220 s	150	0.41 n
HMX	2691-41-0	0.67 s	0.67 s	0.78 n	0.67 s	0.67 s	5.1 n
Hydrazine	302-01-2	2.8 c	100000 s	0.0003 c	6.4 c	100000 s	0.001 c
Hydrazine Sulfate	10034-93-2	2.8 c	N/A	0.0003 c	6.4 c	N/A	0.001 c
Indeno(1,2,3-cd)pyrene	193-39-5	0.76 s	0.76 s	6.E-05 c	0.76 s	0.76 s	0.0002 c
Kepone	143-50-0	0.47 c	1.5	5.E-05 c	1.1 c	5.0	0.0002 c
Lead	7439-92-1	400	N/A	0.015 m	1000	N/A	0.015 m
Lindane	58-89-9	6.6 c	0.04	0.0002 m	15 c	0.04	0.0002 m
Malathion	121-75-5	330 s	15	0.31 n	330 s	97	2.0 n
Manganese	7439-96-5	3600 n	N/A	0.05 M	95000 n	N/A	0.05 M
Mercury	7439-97-6	2 n	N/A	0.002 m	20 n	N/A	0.002 m
Methoxychlor	72-43-5	44 s	44 s	0.04 m	44 s	44 s	0.04 m
Methylene Chloride	75-09-2	150 c	0.03	0.005 m	230 c	0.03	0.005 m
Methyl Ethyl Ketone (2-Butanone)	78-93-3	6400 n	3.6	0.82 n	21000 n	12	2.8 n
Methyl Isobutyl Ketone	108-10-1	1000 n	0.41	0.07 n	3600 n	1.4	0.23 n
2-Methylphenol	95-48-7	3300 n	4.6	0.74 n	6500 s	29	4.7 n
3-Methylphenol	108-39-4	3300 n	8.1	0.74 n	6500 s	29	4.7 n
4-Methylphenol	106-44-5	330 n	1.0	0.08 n	3400 n	6.5	0.47 n
Methyl Tertbutyl Ether	1634-04-4	2400 n	0.09	0.020 h	15000 n	0.09	0.020 h
Metolachlor (Dual)	51218-45-2	390 s	41	2.3 n	390 s	260	15 n
Metribuzin (Sencor)	21087-64-9	740 s	5.6	0.39 n	740 s	36	2.5 n
Naphthalene	91-20-3	100 n	39	0.10 n	320 n	140	0.35 n
Nickel	7440-02-0	1600 n	N/A	0.10 m	41000 n	N/A	0.10 m
Nitrobenzene	98-95-3	21 n	0.02	0.001 n	110 n	0.09	0.005 n
Nitrofurazone	59-87-0	5.7 c	0.002	0.0006 c	13 c	0.008	0.002 c
Nitroguanidine	55-63-0	6700 n	190	1.6 n	12000 s	1200	10 n

APPENDIX A
KDHE TIER 2 RISK-BASED SUMMARY TABLE

		RESIDENTIAL SCENARIOS			NON-RESIDENTIAL SCENARIOS		
Chemical Name	**CAS No.**	**Soil Pathway**	**Soil to Ground Water Protection Pathway**	**Ground Water Pathway**	**Soil Pathway**	**Soil to Ground Water Protection Pathway**	**Ground Water Pathway**
		(mg/kg)	**(mg/kg)**	**(mg/L)**	**(mg/kg)**	**(mg/kg)**	**(mg/L)**
2-Nitropropane	79-46-9	0.91 c	0.0005	9.E-05 c	2.0 c	0.002	0.0003 c
Oxamyl	23135-22-0	1700 n	1.2	0.2 m	17000 n	1.2	0.2 m
Paraquat	1910-42-5	300 n	210	0.07 n	3100 n	1400	0.45 n
Parathion	56-38-2	380 s	98	0.08 n	380 s	380 s	0.52 n
PCBs (Polychlorinated Biphenyl)	1336-36-3	4.3 c	53	0.0005 m	9.5 c	53	0.0005 m
Pendimethalin (Prowl)	40487-42-1	37 s	37 s	0.63 n	37 s	37 s	4.1 n
Pentachlorophenol	87-86-5	71 c	20	0.001 m	160 c	20	0.001 m
Permethrin (Ambush)	52645-53-1	2.4 s	2.4 s	0.002 n	2.4 s	2.4 s	0.01 n
Phenol	108-95-2	32000 s	88	9.0 n	32000 s	560	58 n
Phenylphenol	90-43-7	4400 c	1.4	0.35 c	9800 c	4.7	1.2 c
Phosphine	7803-51-2	20 n	0.02	0.005 n	37 s	0.12	0.03 n
Profluralin	26399-36-0	100 s	100 s	0.09 n	100 s	100 s	0.61 n
Propachlor (Ramrod)	1918-16-7	550 s	4.0	0.20 n	550 s	26	1.3 n
Propazine (Miloguard)	139-40-2	5.1 s	5.1 s	0.29 n	5.1 s	5.1 s	1.9 n
n-Propylbenzene	103-65-1	140 n	11	0.02 n	400 n	44	0.08 n
Pyrene	129-00-0	140 s	140 s	0.14 n	140 s	140 s	0.72 n
Pyridine	110-86-1	33 n	0.01	0.003 n	150 n	0.05	0.009 n
RDX	121-82-4	44 s	0.13	0.008 c	44 s	0.43	0.03 c
Selenium	7782-49-2	390 n	N/A	0.05 m	10000 n	N/A	0.05 m
Silver	7440-22-4	390 n	N/A	0.1 M	10000 n	N/A	0.1 M
Simazine (Princap)	122-34-9	9.3 s	0.13	0.004 m	9.3 s	0.13	0.004 m
Styrene	100-42-5	2400 s	16	0.1 m	2400 s	16	0.1 m
2,4,5-T as Acid	93-76-5	670 n	53	0.15 n	4800 s	340	0.94 n
2,3,7,8-TCDD (Dioxin)	1746-01-6	6.E-05 c	0.02	3.E-08 m	0.0001 c	0.02	3.E-08 m
Terbacil (Sinbar)	5902-51-2	520 s	3.3	0.20 n	520 s	22	1.3 n
Terbufos (Counter)	13071-79-9	1.7 n	0.04	0.0003 n	17 n	0.23	0.002 n
1,1,1,2-Tetrachloroethane	630-20-6	29 c	0.17	0.005 c	45 c	0.33	0.01 c
1,1,2,2-Tetrachloroethane	79-34-5	7.1 c	0.02	0.0007 c	12 c	0.03	0.001 c
Tetrachloroethene (PCE)	127-18-4	79 c	0.18	0.005 m	140 c	0.18	0.005 m
2,3,4,6-Tetrachlorophenol	58-90-2	2000 n	1200	0.27 n	20000 n	6800	1.5 n
Tetryl	479-45-8	45 s	2.2	0.16	45 s	14	1.0 n

APPENDIX A
KDHE TIER 2 RISK-BASED SUMMARY TABLE

		RESIDENTIAL SCENARIOS			NON-RESIDENTIAL SCENARIOS		
Chemical Name	CAS No.	Soil Pathway	Soil to Ground Water Protection Pathway	Ground Water Pathway	Soil Pathway	Soil to Ground Water Protection Pathway	Ground Water Pathway
		(mg/kg)	(mg/kg)	(mg/L)	(mg/kg)	(mg/kg)	(mg/L)
Toluene	108-88-3	930 n	40	1 m	1000 s	40	1 m
TPH GRO		220 n	39	0.500 n	450 n	150	0.500 n
TPH DRO		2000 n	3000	0.500 n	20000 n	15000	0.720 n
Toxaphene	8001-35-2	7.7 c	150	0.003 m	17 c	150	0.003 m
2,4,5-TP (Silvex)	93-72-1	530 n	55	0.05 m	5500 n	55	0.05 m
1,2,4-Trichlorobenzene	120-82-1	600 n	25	0.07 m	4900 n	25	0.07 m
1,1,1-Trichloroethane	71-55-6	680 n	5.5	0.2 m	1800 s	5.5	0.2 m
1,1,2-Trichloroethane	79-00-5	13 c	0.07	0.005 m	20 c	0.07	0.005 m
Trichloroethene (TCE) (see note below)	79-01-6	62 c	0.20	0.005 m	98 c	0.20	0.005 m
2,4,5-Trichlorophenol	95-95-4	6700 n	1600	1.2 n	68000 n	9200	6.7 n
2,4,6-Trichlorophenol	88-06-2	770 c	45	0.05 c	1700 c	150	0.17 c
2(2,4,5-Trichlorophenoxy)propionic acid	93-72-1	530 n	130	0.12 n	5500 n	800	0.73 n
1,2,3-Trichloropropane	96-18-4	0.17 c	0.0004	2.E-05 c	0.28 c	0.0007	4.E-05 c
Triflualine (Treflan)	1582-09-8	500 n	1800	0.05 c	2500 c	6000	0.18 c
1,2,4-Trimethylbenzene	95-63-6	9.7 s	0.85	0.005 n	9.7 s	2.9	0.017 n
1,3,5-Trimethylbenzene	108-67-8	2.5 n	0.24	0.005 n	69.4 n	0.83	0.017 n
2,4,6-Trinitrotoluene	118-96-7	14 s	0.05	0.008 n	14 s	3.3	0.05 n
Vanadium	7440-62-2	550 n	N/A	0.11 n	14000 n	N/A	0.71 n
Vinyl Chloride	75-01-4	0.34 c	0.02	0.002 m	0.54 c	0.02	0.002 m
Xylene (mixed)	1330-20-7	700 s	700 s	10 m	700 s	700 s	10 m
Zinc	7440-66-6	23000 n	N/A	5 M	610000 n	N/A	5 M

Notes

n - non-carcinogenic risk, HI = 1

c - carcinogenic risk, risk = 1×10^{-5}

s - soil saturation

m - primary maximum contaminant level (MCL)

M - secondary maximum contaminant level (MCL)

h - health advisory

N/A - insufficient data to calculate value

At the time of the printing of this document, EPA was reevaluating the toxicity of TCE. Upon completion of EPA's evaluation, the soil pathway value for TCE will change accordingly.

APPENDIX B
CONTAMINANT-SPECIFIC PARAMETERS

Chemical Name	Solubility (mg/L)		Log Kow		Log Koc		Kd for inorganics or Koc * foc for organics	HLC		Diffusivity in Air		Diffusivity in Water	Kp		Volatilization Factor Residential	Volatilization Factor Industrial
Acenaphthene	4.24	a	3.92	a	3.85	a	71	1.55E-04	a	0.04	a	7.69E-06	0.150	m	3.3E+05	3.0E+05
Acenaphthylene	16.1	b	3.55	b	3.49	d	31	1.13E-04	b				0.074	m		
Acetone	1.00E+06	a	-0.24	a	-0.24	a	0.01	3.88E-05	a	0.12	a	1.14E-05	0.0012	m	1.5E+04	1.3E+04
Acetophenone	6.10E+03		1.58		1.55		0.36	1.10E-05				8.70E-06	0.0047			
Acrolein	2.13E+05	b	-0.01	b	1.33	c	0.21	1.22E-04	b	0.11	c	1.22E-05	0.00074	l		
Acrylamide	6.40E+05	b	-0.96	b	-0.94	d	0.0011	1.00E-09	b				0.00024	l		
Acrylonitrile	7.4.E+04	b	0.25	b	-0.07	c	0.01	1.03E-04	b	0.11	c	1.34E-05	0.0014	l	1.6E+05	1.5E+05
Alachlor (Lasso)	242						1.9	2.07E-08	g				0.014	m		
Aldicarb (Temik)	6030	b	1.11	b	1.09	d	0.12	1.44E-09	b				0.00084	m		
Aldrin	0.18	a	6.50	a	6.39	a	24535	1.70E-04	a	0.01	a	4.86E-06	0.0016	l		
Anthracene	0.04	a	4.55	a	4.47	a	297	6.50E-05	a	0.03	a	7.74E-06	0.23	m	1.2E+06	1.1E+06
Antimony and compounds							45						0.0010	l		
Arsenic							29						0.0010	l		
Atrazine	70	b	2.65	b	2.61	d	4.0	4.53E-03	b				0.0083	m		
Barium							41						0.0010	l		
Benzene	1750	a	2.13	a	1.77	a	0.58	5.55E-03	a	0.09	a	9.80E-06	0.021	l	3.8E+03	3.5E+03
Benzidine	500	b	1.66	b	1.63	d	0.43	3.88E-11	b				0.0013	l		
Benzo(a)anthracene	0.01	a	5.70	a	5.60	a	4012	3.35E-06	a	0.05	a	9.00E-06	0.81	l		
Benzo(b)fluoranthene	0.0015	a	6.20	a	6.09	a	12442	1.11E-04	a	0.02	a	5.56E-06	1.2	l		
Benzo(k)fluoranthene	0.0008	a	6.20	a	6.09	a	12442	8.29E-07	a	0.02	a	5.56E-06	1.1	m		
Benzo(a)pyrene	0.0016	a	6.11	a	6.01	a	10149	1.13E-06	a	0.04	a	9.00E-06	1.2	l		
Benzyl Chloride	525	b	2.30	b	1.70	c	0.50	4.15E-04	b	0.07	c	7.80E-06	0.014	l	1.5E+04	1.3E+04
Beryllium							790						0.0010	l		
Bis(2-chloroethyl)ether	1.7.E+04	a	1.21	a	1.19	a	0.15	1.80E-05	a	0.07	a	7.53E-06	0.0021	l	4.5E+04	4.1E+04
Bis(2-chloroisopropyl)ether	1310	b	2.58	b	1.79	c	0.61	1.13E-04	b	0.06	c	6.40E-06	0.010	m	3.1E+04	2.9E+04
Bis(chloromethyl)ether	3.8E+04	b	1.04	b	0.08	c	0.01	1.18E-04	c	0.09	c	9.40E-06	0.00038	m	1.0E+04	9.4E+03
Bis(2-ethylhexyl)phthalate	0.34	a	7.30	a	7.18	a	150031	1.02E-07	a	0.04	a	3.66E-06	0.033	m		
Bromacil	700	g	1.88	g	1.51	g	0.32	1.48E-10	g				0.001	m		
Bromodichloromethane	6740	a	2.10	a	1.74	a	0.55	1.60E-03	a	0.03	a	1.06E-05	0.0058	l	1.2E+04	1.1E+04
Bromoform	3100	a	2.35	a	1.94	a	0.87	5.35E-04	a	0.01	a	1.03E-05	0.0026	l		
Bromomethane	1.5.E+04	b	1.19	b	0.95	c	0.09	6.24E-03	b	0.07	c	1.20E-05	0.0035	l	2.3E+03	2.1E+03
1,3-Butadiene	735	b	1.99	b	2.08	c	1.20	7.36E-02	b	0.10	c	1.10E-05	0.023	l	1.6E+03	1.5E+03
n-Butylbenzene	14	b	4.01	b	3.45	c	28	1.30E-02	b	0.075	c	7.80E-06				
sec-Butylbenzene	17	b	3.94	b	3.34	c	22	1.90E-02	b	0.075	c	7.80E-06				
Butyl Benzyl Phthalate	2.7	a	4.84	a	4.76	a	573	1.26E-06	a	0.02	a	4.83E-06	0.073	m		

APPENDIX B
CONTAMINANT-SPECIFIC PARAMETERS

Chemical Name	Solubility (mg/L)		Log Kow		Log Koc		Kd for inorganics or Koc * foc for organics	HLC		Diffusivity in Air		Diffusivity in Water	Kp		Volatilization Factor Residential	Volatilization Factor Industrial
Cadmium							75						0.0010	l		
Captan	3.3	b	2.45	b	2.41	d	2.6	7.19E-06	b				0.0013	l		
Carbaryl (Sevin)	104	b	2.36	b	2.32	d	2.1	3.46E-09	b				0.0053	m		
Carbazole	7.5	a	3.59	a	3.53	a	34	1.53E-08	a	0.04	a	7.03E-06	0.080	m		
Carbofuran (Furadan)	320	b	1.61	b	1.58	d	0.38	9.20E-05	b				0.0038	m		
Carbon Disulfide	1190	a	2.00	a	1.66	a	0.46	3.03E-02	a	0.10	a	1.00E-05	0.024	l	1.6E+03	1.4E+03
Carbon Tetrachloride	793	a	2.73	a	2.24	a	1.74	3.04E-02	a	0.08	a	8.80E-06	0.022	l	2.9E+03	2.7E+03
Chlordane	0.06	a	6.32	a	5.08	a	1211	4.86E-05	a	0.01	a	4.37E-06	0.052	l		
Chlorobenzene	472	a	2.86	a	2.34	a	2.2	3.70E-03	a	0.07	a	8.70E-06	0.041	l	9.2E+03	8.4E+03
Chloroform	7920	a	1.92	a	1.60	a	0.40	3.67E-03	a	0.10	a	1.00E-05	0.0089	l	3.7E+03	3.4E+03
Chloromethane	5330	b	0.91	b	1.54	c	0.35	8.82E-03	b	0.11	c	6.50E-06	0.0042	l	7.3E+03	6.7E+03
Chlorpyrifos (Lorsban/Dursban)	1.12	b	5.26	b	5.17	d	1482	2.87E-05	f				0.046	m		
Chromium (trivalent)							2.E+06						0.0010	l		
Chromium (hexavalent)							19									
Chrysene	0.0016	a	5.70	a	5.60	a	4012	9.46E-05	a	0.02	a	6.21E-06	0.81	l		
Copper													0.0010	l		
Cyanazine (Bladex)	171	b	2.20	b	2.16	d	1.5	1.00E-10	b				0.0024	m		
Cyanide (free)							9.9						0.0010	l		
Dacthal	0.50						56	2.16E-06	g				0.059	m		
DDD	0.09	a	6.10	a	6.00	a	9922	4.00E-06	a	0.02	a	4.76E-06	0.28	l		
DDE	0.12	a	6.76	a	6.65	a	44194	2.10E-05	a	0.01	a	5.87E-06	0.24	l		
DDT	0.03	a	6.53	a	6.42	a	26259	8.10E-06	a	0.01	a	4.95E-06	0.43	l		
Diazinon	40	b	3.35	b	3.29	d	20						0.013	m		
Dibenzo(a,h)anthracene	0.0025	a	6.69	a	6.58	a	37718	1.47E-08	a	0.02	a	5.18E-06	2.7	l		
Dibenzofuran	10.0	b	4.20	b	4.13	d	135	1.26E-05	b	0.06	q	1.00E-05	0.173	m	7.8E+05	7.1E+05
1,4-Dibromobenzene	3.45		3.75		3.05	e	11	4.00E+02	j				0.034	m		
Dibromochloromethane	2600	b	2.17	b	1.80	e	0.63	7.83E-04	b				0.0035	m		
1,2-Dichlorobenzene	156	a	3.43	a	2.79	a	6.2	1.90E-03	a	0.07	a	7.90E-06	0.061	l	2.2E+04	2.0E+04
1,4-Dichlorobenzene	74.0	a	3.42	a	2.79	a	6.1	2.43E-03	a	0.07	a	7.90E-06	0.062	l	1.9E+04	1.8E+04
Dichlorodifluoromethane	280	b	2.16	b	1.76	c	0.58	3.43E-01	b	0.08	c	1.05E-05	0.012	l	1.1E+03	1.0E+03
1,1-Dichloroethane	5060	a	1.79	a	1.50	a	0.31	5.62E-03	a	0.07	a	1.05E-05	0.0089	l	3.3E+03	3.0E+03
1,2-Dichloroethane	8520	a	1.47	a	1.24	a	0.17	9.79E-04	a	0.10	a	9.90E-06	0.0053	l	5.2E+03	4.8E+03
1,1-Dichloroethene	2250	a	2.13	a	1.77	a	0.58	2.61E-02	a	0.09	a	1.04E-05	0.016	l	1.9E+03	1.8E+03
1,2-Dichloroethene (cis)	3500	a	1.86	a	1.55	a	0.36	4.08E-03	a	0.07	a	1.13E-05	0.010	m	4.0E+03	3.7E+03
1,2-Dichloroethene (trans)	6300	a	2.07	a	1.72	a	0.52	9.38E-03	a	0.07	a	1.19E-05	0.014	m	3.2E+03	2.9E+03

APPENDIX B
CONTAMINANT-SPECIFIC PARAMETERS

Chemical Name	Solubility (mg/L)		Log Kow		Log Koc		Kd for inorganics or Koc * foc for organics	HLC		Diffusivity in Air		Diffusivity in Water	Kp		Volatilization Factor Residential	Volatilization Factor Industrial
2,4-Dichlorophenol	4500	a	3.08	a	3.03	d	11	3.16E-06	a	0.03	a	8.77E-06	0.023	l		
2,4-Dichlorophenoxyacetic acid (2,4-D	677	b	2.70	b	2.65	d	4.5	1.02E-08	b				0.0084	m		
1,2-Dichloropropane	2800	a	1.97	a	1.64	a	0.43	2.80E-03	a	0.08	a	8.73E-06	0.010	l	5.0E+03	4.6E+03
1,3-Dichloropropene	2800	a	2.00	a	1.66	a	0.46	1.77E-02	a	0.06	a	1.00E-05	0.0055	l	2.5E+03	2.3E+03
Dichlorvos	1.0.E+04	b	1.43	b	1.41	d	0.25	1.54E-03	b				0.0010	l		
Dieldrin	0.20	a	5.37	a	4.33	a	214	1.51E-05	a	0.01	a	4.74E-06	0.016	l		
Diethyl Phthalate	1080	a	2.50	a	2.46	a	2.87	4.50E-07	a	0.03	a	6.35E-06	0.0048	l		
2,4-Dimethylphenol	7870	a	2.36	a	2.32	a	2.09	2.00E-06	a	0.06	a	8.69E-06	0.015	l		
2,4-Dinitrophenol	2790	a	1.55	a	1.52	d	0.33	4.43E-07	a	0.03	a	9.06E-06	0.0018	l		
2,4-Dinitrotoluene	270	a	2.01	a	1.98	a	0.95	9.26E-08	a	0.20	a	7.06E-06	0.0038	l		
2,6-Dinitrotoluene	180	a	1.87	a	1.84	a	0.69	7.47E-07	a	0.03	a	7.26E-06	0.0025	l		
Di-*n*-octyl Phthalate	0.02	a	8.06	a	7.92	a	8.4.E+05	6.68E-05	a	0.02	a	3.58E-06	27	m		
1,4-Dioxane	1.00E+06	b	-0.39	b	-0.23	e	0.01	4.80E-06	b				0.00036	l		
Diuron	42	g	2.80	g	2.68	g	4.77	5.03E-10	g				0.007	m		
Endosulfan	0.51	a	4.10	a	3.33	a	21	1.12E-05	a	0.01	a	4.55E-06	0.0033	m		
Endrin	0.25	a	5.06	a	4.09	a	122	7.52E-06	a	0.01	a	4.74E-06	0.016	l		
EPTC (Ethyl-dithiopropylcarbamate, s	370	b	3.21	b	3.16	d	14	1.07E-04	b				0.025	m		
Eradicane	344						2.0									
Ethylbenzene	169	a	3.14	a	2.56	a	3.7	7.88E-03	a	0.08	a	7.80E-06	0.074	l	8.0E+03	7.3E+03
Ethylene dibromide	4180	b	1.96	b	1.45	c	0.28	7.43E-04	b	0.07	c	8.06E-06	0.0034	l	8.4E+03	7.6E+03
Fluoranthene	0.21	a	5.12	a	5.03	a	1080	1.61E-05	a	0.03	a	6.35E-06	0.36	l		
Fluorene	2.0	a	4.21	a	4.14	a	138	6.36E-05	a	0.04	a	7.88E-06	0.36	m	7.6E+05	7.0E+05
Fonofos (Dyfonate)	13	g					19	6.48E-06	g				0.038	m		
Formaldehyde	5.50E+05	b	-0.05	b	-0.05	d	0.01	3.36E-07	b				0.0022	l		
Furan	1.0.E+04	b	1.34	b	1.08	c	0.12	5.40E-03	b	0.10	c	1.22E-05	0.0065	m	2.1E+03	2.0E+03
Glyphosate (Roundup)	1.3.E+04	g					21	1.38E-12	g				0.00018	m		
Heptachlor	0.18	a	6.26	a	6.15	a	14251	1.48E+00	b	0.01	a	5.69E-06	0.011	l	9.2E+04	
Heptachlor Epoxide	0.20	a	5.00	a	4.92	a	823	9.50E-06	a	0.01	a	4.23E-06	0.055	m		
Hexachlorobenzene	6.2	a	5.89	a	4.74	a	553	1.32E-03	a	0.05	a	5.91E-06	0.21	l		
Hexachlorobutadiene	3.2	a	4.81	a	4.73	a	535	8.15E-03	a	0.06	a	6.16E-06	0.12	l		
Hexachloroethane	50	a	4.00	a	3.25	a	18	3.89E-03	a	0.00	a	6.80E-06	0.042	l		
n-Hexane	12	b	4.00	b	2.95	c	8.9	1.43E-02	b	0.20	c	7.77E-06	0.33	m	5.6E+03	5.1E+03
HMX	5	n	0.26	n	0.54	n	0.035	2.60E-15	n				0.000046	m		
Hydrazine	1.00E+06	b	-2.07	b	-2.03	d	0.00009	4.61E-04	l				0.000041	l		
Hydrazine sulfate													0.000041	l		

APPENDIX B
CONTAMINANT-SPECIFIC PARAMETERS

Chemical Name	Solubility (mg/L)		Log Kow		Log Koc		Kd for inorganics or Koc * foc for organics	HLC		Diffusivity in Air		Diffusivity in Water	Kp		Volatilization Factor Residential	Volatilization Factor Industrial
Indeno(1,2,3-cd)pyrene	0.000022	a	6.65	a	6.54	a	34453	1.60E-06	a	0.02	a	5.66E-06	1.9	l		
Kepone	7.6	b	5.30	b	5.21	d	1622	2.50E-08	b				0.0030	m		
Lead													0.0010	l		
Lindane	6.8	a	3.73	a	3.03	a	11	1.40E-05	a	0.01	a	7.34E-06	0.014	l		
Malathion	143	b	2.86	b	2.34	e	2.2	4.89E-09	b				0.0009	m		
Manganese													0.0010	l		
Mercury							52	1.14E-02	b	0.03	a	6.30E-06	0.0010	l		
Methoxychlor	0.05	a	5.08	a	4.99	a	986	1.58E-05	a	0.02	a	4.46E-06	0.043	m		
Methylene Chloride	13000	a	1.25	a	1.07	a	0.12	2.19E-03	a	0.10	a	1.17E-05	0.0045	l	3.2E+03	3.0E+03
Methyl Ethyl Ketone	2.23E+05	b	0.28	b	0.65	c	0.05	5.59E-05	b	0.09	c	9.80E-06	0.0011	l	1.7E+04	1.6E+04
Methyl Isobutyl Ketone	1.90E+04	b	1.19	b	2.11	c	1.3	1.38E-04	b	0.08	c	7.80E-06	0.0033	m	3.7E+04	3.3E+04
2-Methylphenol (o-Creosol)	3.10E+04	b	2.06	b	1.04	c	0.11	1.10E-06								
3-Methylphenol (m-Creosol)	2.50E+04	b	2.06	b	1.54	c	0.35	1.50E-06								
4-Methylphenol (p-Creosol)	2.15E+04	b	2.06	b	1.69	c	0.49	1.00E-06								
Methyl Tertbutyl Ether	5.00E+04	n	1.24	n	1.04	n	0.11	5.85E-04	n	0.08	o		0.0026	m	6.7E+03	6.1E+03
Metolachlor (Dual)	488	g					0.70	2.41E-08	g				0.0059	m		
Metribuzin (Sencor)	1200	b	1.70	b			0.52	8.78E-02	b				0.0015	m		
Naphthalene	31	a	3.36	a	3.30	a	20	4.83E-04	a	0.06	a	7.50E-06	0.069	l	8.4E+04	7.6E+04
Nickel							65						0.0010	l		
Nitrobenzene	2090	a	1.84	a	1.81	a	0.64	2.40E-05	a	0.08	a	8.60E-06	0.0070	m	6.3E+04	5.8E+04
Nitrofurazone													0.00017	m		
Nitroguanidine	1950.00	p	1.62	p	2.77	k	5.9	2.71E-07	p				0.00011	p		
2-Nitropropane	2.E+04	b	0.87	b	0.86	d	0.07	1.23E-04	b				0.0010	l		
Oxamyl	3.E+05	g					0.09	3.85E-13	g				0.00019	m		
Paraquat	1.E+06	h					155	1.00E-09	k				0.0053	D		
Parathion (ethyl)	6.5	b	3.83	b	3.77	d	58	5.65E-07	b				0.017	l		
PCBs (Polychlorinated Biphenyl)	0.07	b	6.04	b	5.49	a	3090	2.60E-03	b				0.0050	D		
Pendimethalin (Prowl)	0.28	g					134	1.21E-05	g				0.000037	m		
Pentachlorophenol	1950	a	5.09	a	5.00	d	1009	2.44E-08	a	0.06	a	6.10E-06	0.65	l		
Permethrin (Ambush)	0.01	g					393	1.87E-06	g				45	m		
Phenanthrene	1.15	b	4.55	b	4.47	d	297	2.33E-05	b				0.23	l		
Phenol	8.E+04	a	1.48	a	1.46	a	0.29	3.97E-07	a	0.08	a	9.10E-06	0.0055	l		
Phenylphenol													0.027	m		
Phosphine	370	b		b									0.0012	m		
Profluralin	0.10	g					1000	2.88E-04	g				0.000015	m		

APPENDIX B
CONTAMINANT-SPECIFIC PARAMETERS

Chemical Name	Solubility (mg/L)		Log Kow		Log Koc		Kd for inorganics or Koc * foc for organics	HLC		Diffusivity in Air		Diffusivity in Water	Kp		Volatilization Factor Residential	Volatilization Factor Industrial
Propachlor (Ramros)	613	g					0.80	1.05E-07	g				0.0034	m		
Propazine (Miloguard)	3.0	g					1.6	1.28E-08	g				0.0091	m		
n-Propylbenzene	14.0		4.01		3.45		28	1.30E-02		0.075		7.80E-06				
Pyrene	0.14	a	5.11	a	5.02	a	1055	1.10E-05	a	0.03	a	7.24E-06	0.33	m		
Pyridine	1.00E+06	b	0.67	b	0.66	d	0.05	8.88E-06	b	0.09	o		0.0018	m	4.2E+04	3.9E+04
RDX	6.10E+01	n	0.87	n	1.80	n	0.63	1.20E-05	n				0.0018	m		
Selenium							5.0						0.0010	l		
Silver							8.3						0.0010	l		
Simazine (Princap)	6.2	g					1.4	9.67E-10	g				0.0040	m		
Styrene	310	a	2.94	a	2.89	a	7.8	2.75E-03	a	0.07	a	8.00E-06	0.055	l	2.0E+04	1.8E+04
2,4,5-Trichlorophenoxyacetic acid	268	b	3.31	b	3.25	d	18	8.68E-09	b				0.0088	m		
2,3,7,8-TCDD (Dioxin)	7.9E-06	b	6.53	b	6.42	d	26259	7.92E-05	b				1.4	l		
Terbacil (Sinbar)	710	g					0.63	1.88E-10	g				0.0020	m		
Terbufos (Counter)	4.5	g					6.5	2.67E-05	g				0.050	m		
1,1,1,2-Tetrachloroethane	1100	b	2.63	b	2.16	e	1.45	2.42E-03	b	0.07	c	7.90E-06	0.028	m	9.5E+03	8.7E+03
1,1,2,2-Tetrachloroethane	2970	a	2.39	a	1.97	a	0.94	3.45E-04	a	0.07	a	7.90E-06	0.0090	l	2.0E+04	1.9E+04
Tetrachloroethene (PCE)	200	a	2.67	a	2.19	a	1.56	1.84E-02	a	0.07	a	8.20E-06	0.048	l	3.7E+03	3.3E+03
2,3,4,6-Tetrachlorophenol	100	b	4.44	b	4.36	d	232	4.39E-06	b				0.11	m		
Tetryl	80	p	1.65	p	1.69	p	0.49	2.69E-11	p				0.0005	p		
Toluene	526	a	2.75	a	2.26	a	1.80	6.64E-03	a	0.09	a	8.60E-06	0.045	l	5.8E+03	5.3E+03
TPH GRO	12	b	4.00	b	2.95	c	8.90	1.43E-02	b	0.20	c	7.77E-06	0.330	m	5.6E+03	5.1E+03
TPH DRO	0.14	a	5.11	a	5.02	a	1055	1.10E-05	a	0.03	a	7.24E-06	0.330	m		
Toxaphene	0.74	a	5.50	a	5.41	a	2551	6.00E-06	a	0.01	a	4.34E-06	0.015	l		
2,4,5-TP (Silvex)	140	b	3.80	b	3.74	d	54	7.83E-11	b				0.011	l		
1,2,4-Trichlorobenzene	300	a	4.01	a	3.25	a	18	1.42E-03	a	0.03	a	8.23E-06	0.10	l	6.5E+04	5.9E+04
1,1,1-Trichloroethane	1330	a	2.48	a	2.04	a	1.10	1.72E-02	a	0.08	a	8.80E-06	0.017	l	3.1E+03	2.9E+03
1,1,2-Trichloroethane	4420	a	2.05	a	1.70	a	0.50	9.13E-04	a	0.08	a	8.80E-06	0.0084	l	9.2E+03	8.4E+03
Trichloroethene (TCE)	1100	a	2.71	a	2.22	a	1.68	1.03E-02	a	0.08	a	9.10E-06	0.018	l	4.7E+03	4.3E+03
2,4,5-Trichlorophenol	1200	a	3.90	a	3.83	d	68	4.33E-06	a	0.03	a	7.03E-06	0.052	m		
2,4,6-Trichlorophenol	800	a	3.70	a	3.64	d	43	7.79E-06	a	0.03	a	6.25E-06	0.050	l		
2(2,4,5-Trichlorophenoxy)propionic ac	140	b	3.80	b	3.74	d	54	7.83E-11	b				0.011	l		
1,2,3-Trichloropropane	1750	b	2.25	b	1.86	e	0.72	4.09E-04	b	0.07	c	7.90E-06	0.010	m	1.7E+04	1.5E+04
Trifluralin (Treflan)	8.1	b	5.32	b	5.23	d	1698	2.64E-05	b				0.11	m		
1,2,4-Trimethylbenzene	0.26		3.63		3.57		37	5.70E-03		0.075		7.10E-06				
1,3,5-Trimethylbenzene	50	c	3.42		2.91		8.2	7.70E-03		0.075		7.10E-06				

APPENDIX B
CONTAMINANT-SPECIFIC PARAMETERS

Chemical Name	Solubility (mg/L)		Log Kow		Log Koc		Kd for Inorganics or Koc * foc for organics	HLC		Diffusivity In Air		Diffusivity in Water	Kp		Volatilization Factor Residential	Volatilization Factor Industrial
2,4,6-Trinitrotoluene	120	n	1.60	n	0.20	n	0.016	4.90E-09	n				0.0011	m		
Vanadium							1000						0.0010	l		
Vinyl Chloride	2760	a	1.50	a	1.27	a	0.18	2.70E-02	a	0.11	a	1.23E-06	0.0073	l	1.3E+03	1.2E+03
Xylene (mixed)	175	c	3.17	c	2.59	e	3.9	5.71E-03	c	0.08	c	8.40E-06	0.080	l	9.4E+03	8.6E+03
Zinc							62						0.0010	l		

Footnotes

a=EPA's Soil Screening Guidance (May 1996)

b = Superfund Chemical Data Matrix http://www.epa.gov/superfund/oerr/products/scdm/scdm.htm

c= from *EPA Region IX PRG* list, 1996

d = calculated using nonionizing organic compound equation #70 from EPA's Soil Screening Guidance (May 1996)

e = calculated using equation for VOCs, chlorinated benzenes, and certain chlorinated pesticides [equation #71 from EPA's Soil Screening Guidance (May 1996)]

f = Table A-1 Water Solubility, Vapor Pressure, Henry's Law Constant, Koc, and Kow Dat http://www3.bae.ncsu.edu/info1/courses/bae573/models/gleams/www-docs/tabp2.txt

g = ARS Pesticide Properties http://www.arsusda.gov/rsml/ppdb3

h = Table P-2 Characteristics of Pesticides sorted by Common Name

i = calculated using equation #68 from EPA's Soil Screening Guidance: Technical Background Document (May 1996): HLC = (VP)(M)/(S)

j = Schwarzenbch et al., 1993 Properties of Some Organic Compounds http://www.uc.edu/www/geology/org-cont/refer/propert.html

k = HSDB *Hazardous Substance Data Ban* . Online search for specified chemicals. 1994

l = USEPA, Dermal Exposure Assessment Principles & Applications, EPA/600/8-9/011B, January 1992

m = Calculated Kp using equation from EPA's Dermal Exposure Assessment 1/92: log Kp=-2.72+0.71log kow - 0.0061 MW

n =Agency for Toxic Substances and Disease Registry

o =EPA March93 451/R-93/001. Air/Superfund National Technical Guidance Study Series, Model for Estimating Air Emission Rates from Superfund Remedial Action

p = U.S. Army Biomedical Research & Development Laboraty; Technical Report 8901

q = EPA Region 9 PRG Tables, 2002

Notes:

Chemical/Physical Parameters not found for Eradicane, Hydrazine sulfate, nitrofurazone, phenylphenol, and phosphine

Solubility: the ability or tendency of one substance to blend uniformly with another

Kow: octanol-water partition coefficient

Koc: organic carbon normalized soil-water partition coefficient for organic compounds

Kd: soil-water partition coefficient for inorganic constituents

HLC: Henry's Law constant (atm-m^3/mol)

H': Henry's Law constant (unitless)

APPENDIX C
CONTAMINANT TOXICITY DATA

Chemical Name	Weight of Evidence CLASS	SFo (kg-day/mg)		SFi (kg-day/mg)		SFd (kg-day/mg)		RfDo (mg/kg-day)		RfDi (mg/kg-day)		RfDd (mg/kg-day)	
Acenaphthene	NA							6.00E-02	i	6.00E-02	r	6.00E-02	r
Acenaphthylene	D												
Acetone	D							1.00E-01	i	1.00E-01	r	1.00E-01	r
Acetophenone								1.00E-01	i	5.71E-06	i		
Acrolein	C							2.00E-02	h	5.71E-06	c	2.00E-02	r
Acrylamide	B2	4.55E+00	i	4.55E+00	c	4.55E+00	r	2.00E-04	i	2.00E-04	r	2.00E-04	r
Acrylonitrile	B1	5.40E-01	i	2.38E-01	c	5.40E-01	r	1.00E-03	h	5.71E-04	c	1.00E-03	r
Alachlor (Lasso)	B2	8.05E-02	h	8.00E-02	r	8.05E-02	r	1.00E-02	i	1.00E-02	r	1.00E-02	r
Aldicarb (Temik)	D							1.00E-03	i	1.00E-03	r	1.00E-03	r
Aldrin	B2	1.70E+01	i	1.72E+01	r	1.70E+01	r	3.00E-05	i	3.00E-05	r	3.00E-05	r
Anthracene	D							3.00E-01	i	3.00E-01	r	3.00E-01	r
Antimony and compounds	D							4.00E-04	i				
Arsenic	A	1.50E+00	i	1.51E+01	c	1.50E+00	r	3.00E-04	i				
Atrazine	C	2.22E-01	h	2.22E-01	r	2.22E-01	r	3.50E-02	h	3.50E-02	r	3.50E-02	r
Barium	D							7.00E-02	i	1.43E-04	h		
Benzene	A	2.90E-02	i	2.90E-02	c	2.90E-02	r	3.00E-03	n	1.71E-03	n	3.00E-03	r
Benzidine	A	2.30E+02	i	2.30E+02	r	2.30E+02	r	3.00E-03	i	3.00E-03	r	3.00E-03	r
Benzo(a)anthracene	B2	7.30E-01	n	3.10E-01	n	7.30E-01	r						
Benzo(b)fluoranthene	B2	7.30E-01	n	3.10E-01	n	7.30E-01	r						
Benzo(k)fluoranthene	B2	7.30E-02	n	3.10E-02	n	7.30E-02	r						
Benzo(a)pyrene	B2	7.30E+00	n	3.10E+00	n	7.30E+00	r						
Benzyl Chloride	B2	1.70E-01	i	1.70E-01	r	1.70E-01	r						
Beryllium	B1			8.40E+00	c			2.00E-03	i	5.71E-06	i	2.00E-03	r
Bis(2-chloroethyl)ether	B2	1.10E+00	i	1.16E+00	c	1.10E+00	r						
Bis(2-chloroisopropyl)ether	C	7.00E-02	h	3.50E-02	c	7.00E-02	r	4.00E-02	i	4.00E-02	r	4.00E-02	r
Bis(chloromethyl)ether	A	2.20E+02	i	2.17E+02	c	2.20E+02	r						
Bis(2-ethylhexyl)phthalate	B2	1.40E-02	i	1.40E-02	r	1.40E-02	r	2.00E-02	i	2.20E-02	r	2.20E-02	r
Bromacil	C							1.00E-01	e	1.00E-01	r	1.00E-01	r
Bromodichloromethane	B2	6.20E-02	i	6.20E-02	r	6.20E-02	r	2.00E-02	i	2.00E-02	r	2.00E-02	r
Bromoform	B2	7.90E-03	i	3.85E-03	c	7.90E-03	r	2.00E-02	i	2.00E-02	r	2.00E-02	r
Bromomethane	D							1.40E-03	i	1.43E-03	c	1.40E-03	r
n-Butylbenzene								1.00E-02	n	1.00E-02	n	1.00E-02	n
sec-Butylbenzene								1.00E-02	n	1.00E-02	n	1.00E-02	n
1,3-Butadiene	B2	9.80E-01	r	9.80E-01	c	9.80E-01	r						
Butyl Benzyl Phthalate	C							2.00E-01	i	2.00E-01	r	2.00E-01	r

APPENDIX C
CONTAMINANT TOXICITY DATA

Chemical Name	Weight of Evidence CLASS	SFo (kg-day/mg)		SFi (kg-day/mg)		SFd (kg-day/mg)		RfDo (mg/kg-day)		RfDi (mg/kg-day)		RfDd (mg/kg-day)	
Cadmium	B1 (inhalation)			6.30E+00	c			5.00E-04	i				
Captan	B2	3.50E-03	h	3.50E-03	r	3.50E-03	r	1.30E-01	i	1.30E-01	r	1.30E-01	r
Carbaryl (Sevin)								1.00E-01	i	1.00E-01	r	1.00E-01	r
Carbazole	B2	2.00E-02	h	2.00E-02	r	2.00E-02	r						
Carbofuran (Furadan)								5.00E-03	i	5.00E-03	r	5.00E-03	r
Carbon Disulfide	NA							1.00E-01	i	2.00E-01	i	1.00E-01	r
Carbon Tetrachloride	B2	1.30E-01	i	5.25E-02	c	1.30E-01	r	7.00E-04	i	5.71E-04	n	7.00E-04	r
Chlordane	B2	3.50E-01	i	3.50E-01	c	3.50E-01	r	5.00E-04	i	2.29E-05	r	5.00E-04	r
Chlorobenzene	D							2.00E-02	i	5.71E-03	h	2.00E-02	r
Chloroform	B2	6.10E-03	i	8.05E-02	c	6.10E-03	r	1.00E-02	i	1.00E-02	r	1.00E-02	r
Chloromethane	C	1.30E-02	h	6.30E-03	c	1.30E-02	r						
Chlorpyrifos (Lorsban/Dursban)	D							3.00E-03	i	3.00E-03	r	3.00E-03	r
Chromium (trivalent)	D							1.00E+00	i				
Chromium (hexavalent)	A			4.20E+01	c			5.00E-03	i				
Chrysene	B2	7.30E-03	n	3.10E-03	n	7.30E-03	r						
Copper	D							3.71E-02	h				
Cyanazine (Bladex)	C	8.40E-01	h	8.40E-01	r	8.40E-01	r	2.00E-03	h	2.00E-03	r	2.00E-03	r
Cyanide (free)	D							2.00E-02	i				
Dacthal								1.00E-02	i	1.00E-02	r	1.00E-02	r
DDD	B2	2.40E-01	i	2.40E-01	r	2.40E-01	r						
DDE	B2	3.40E-01	i	3.40E-01	r	3.40E-01	r						
DDT	B2	3.40E-01	i	3.40E-01	c	3.40E-01	r	5.00E-04	i	5.00E-04	r	5.00E-04	r
Diazinon								9.00E-04	h	9.00E-04	r	9.00E-04	r
Dibenzo(a,h)anthracene	B2	7.30E+00	n	3.10E+00	n	7.30E+00	r						
Dibenzofuran								4.00E-03	n	4.00E-03	n	4.00E-03	n
1,4-Dibromobenzene								1.00E-02	i	1.00E-02	r	1.00E-02	r
Dibromochloromethane	C	8.40E-02	i	8.40E-02	r	8.40E-02	r	2.00E-02	i	2.00E-02	r	2.00E-02	r
1,2-Dichlorobenzene	D							9.00E-02	i	5.71E-02	c	9.00E-02	r
1,4-Dichlorobenzene	C	2.40E-02	h	2.40E-02	r	2.40E-02	r	2.00E-01	n	2.29E-01	c	2.29E-01	r
Dichlorodifluoromethane	D							2.00E-01	i	5.71E-02	h	2.00E-01	r
1,1-Dichloroethane	C							1.00E-01	h	1.43E-01	c	1.00E-01	r
1,2-Dichloroethane	B2	9.10E-02	i	9.10E-02	c	9.10E-02	r						
1,1-Dichloroethene	C	6.00E-01	i	1.75E-01	l	6.00E-01	r	9.00E-03	i	9.00E-03	r	9.00E-03	r
1,2-Dichloroethene (cis)	D							1.00E-02	h	1.00E-02	r	1.00E-02	r

APPENDIX C
CONTAMINANT TOXICITY DATA

Chemical Name	Weight of Evidence CLASS	SFo (kg-day/mg)		SFi (kg-day/mg)		SFd (kg-day/mg)		RfDo (mg/kg-day)		RfDi (mg/kg-day)		RfDd (mg/kg-day)	
1,2-Dichloroethene (trans)	D							2.00E-02	i	2.00E-02	r	2.00E-02	r
2,4-Dichlorophenol								3.00E-03	i	3.00E-03	r	3.00E-03	r
2,4-Dichlorophenoxyacetic acid (2,4-D)	D							1.00E-02	i	1.00E-02	r	1.00E-02	r
1,2-Dichloropropane	B2	6.80E-02	h	6.80E-02	r	6.80E-02	r	1.10E-03	r	1.10E-03	i	1.10E-03	r
1,3-Dichloropropene	B2	1.80E-01	h	1.30E-01	c	1.80E-01	r	3.00E-04	i	5.71E-03	c	3.00E-04	r
Dichlorvos	B2	2.90E-01	i	2.90E-01	r	2.90E-01	r	5.00E-04	i	1.43E-04	c	5.00E-04	r
Dieldrin	B2	1.60E+01	i	1.61E+01	c	1.60E+01	r	5.00E-05	i	5.00E-05	r	5.00E-05	r
Diethyl Phthalate	D							8.00E-01	i	8.00E-01	r	8.00E-01	r
2,4-Dimethylphenol								2.00E-02	i	2.00E-02	r	2.00E-02	r
2,4-Dinitrophenol								2.00E-03	i	2.00E-03	r	2.00E-03	r
2,4-Dinitrotoluene	B2	6.80E-01	i	6.80E-01	r	6.80E-01	r	2.00E-03	i	2.00E-03	r	2.00E-03	r
2,6-Dinitrotoluene	B2	6.80E-01	i	6.80E-01	r	6.80E-01	r	1.00E-03	h	1.00E-03	r	1.00E-03	r
Di-n-octyl Phthalate	NA							2.00E-02	h	2.00E-02	r	2.00E-02	r
1,4-Dioxane	B2	1.10E-02	i	1.10E-02	r	1.10E-02	r						
Diuron								2.00E-03	i2	2.00E-03	r	2.00E-03	r
Endosulfan								6.00E-03	i	6.00E-03	r	6.00E-03	r
Endrin	D							3.00E-04	i	3.00E-04	r	3.00E-04	r
EPTC (Ethyl-dithiopropylcarbamate, s-)								2.50E-02	i	2.50E-02	r	2.50E-02	r
Eradicane													
Ethylbenzene	D							1.00E-01	I	2.90E-01	c	1.00E-01	r
Ethylene dibromide	B2	8.50E+01	i	7.70E-01	c	8.50E+01	r	5.70E-05	r	5.70E-05	h	5.70E-05	r
Fluoranthene	D							4.00E-02	i	4.00E-02	r	4.00E-02	r
Fluorene	D							4.00E-02	i	4.00E-02	r	4.00E-02	r
Fonofos (Dyfonate)								2.00E-03	i	2.00E-03	r	2.00E-03	r
Formaldehyde	B1 (inhalation)			4.55E-02	c			1.50E-01	i			1.50E-01	r
Furan								1.00E-03	i	1.00E-03	r	1.00E-03	r
Glyphosate (Roundup)	D							1.00E-01	i	1.00E-01	r	1.00E-01	r
Heptachlor	B2	4.50E+00	i	4.55E+00	c	4.50E+00	r	5.00E-04	i	5.00E-04	r	5.00E-04	r
Heptachlor Epoxide	B2	9.10E+00	i	9.10E+00	c	9.10E+00	r	1.30E-05	i	1.30E-05	r	1.30E-05	r
Hexachlorobenzene	B2	1.60E+00	i	1.61E+00	c	1.60E+00	r	8.00E-04	i	8.00E-04	r	8.00E-04	r
Hexachlorobutadiene	C	7.80E-02	i	7.70E-02	c	7.80E-02	r	2.00E-04	h	2.00E-04	r	2.00E-04	r
Hexachloroethane	C	1.40E-02	i	1.40E-02	c	1.40E-02	r	1.00E-03	i	1.00E-03	r	1.00E-03	r
n-Hexane								6.00E-02	h	5.71E-02	c	6.00E-02	r
HMX								5.00E-02	i	5.00E-02	i	5.00E-02	r

APPENDIX C
CONTAMINANT TOXICITY DATA

Chemical Name	Weight of Evidence CLASS	SFo (kg-day/mg)		SFI (kg-day/mg)		SFd (kg-day/mg)		RfDo (mg/kg-day)		RfDI (mg/kg-day)		RfDd (mg/kg-day)	
Hydrazine	B2	3.00E+00	i	1.72E+01	c	3.00E+00	r						
Hydrazine sulfate	B2	3.00E+00	i	1.72E+01	c	3.00E+00	r						
Indeno(1,2,3-cd)pyrene	B2	7.30E-01	n	3.10E-01	n	7.30E-01	r						
Kepone		1.80E+01	n	1.80E+01	r	1.80E+01	r						
Lead	B2												
Lindane	B2 - C	1.30E+00	h	1.30E+00	r	1.30E+00	r	3.00E-04	i	3.00E-04	r	3.00E-04	r
Malathion								2.00E-02	i	2.00E-02	r	2.00E-02	r
Manganese	D							4.67E-02	i	1.40E-05	c	4.67E-02	r
Mercury	D							3.00E-04	h	8.57E-05	c	3.00E-04	r
Methoxychlor	D							5.00E-03	i	5.00E-03	r	5.00E-03	r
Methylene Chloride	B2	7.50E-03	i	1.65E-03	c	7.50E-03	r	6.00E-02	i	8.57E-01	c	6.00E-02	r
Methyl Ethyl Ketone	D							6.00E-01	i	2.86E-01	c	6.00E-01	r
Methyl Isobutyl Ketone								8.00E-02	h	2.29E-02	c	8.00E-02	r
2-Methylphenol								5.00E-02	i	5.00E-02	i	5.00E-02	i
3-Methylphenol								5.00E-02	i	5.00E-02	i	5.00E-02	i
4-Methylphenol								5.00E-03	h	5.00E-03	h	5.00E-03	h
Methyl Tertbutyl Ether								5.00E-02	n	8.57E-01	c	5.00E-02	r
Metolachlor (Dual)	C							1.50E-01	i	1.50E-01	r	1.50E-01	r
Metribuzin (Sencor)	D							2.50E-02	i	2.50E-02	r	2.50E-02	r
Naphthalene	D							2.00E-02	i	8.57E-04	i	2.00E-02	r
Nickel	D							2.00E-02	i				
Nitrobenzene	D							5.00E-04	i	5.71E-04	c	5.00E-04	r
Nitrofurazone	B2	1.50E+00	h	9.40E+00	h	1.50E+00	r						
Nitroguanidine								1.00E-01	i	1.00E-01	r	1.00E-01	r
2-Nitropropane	B2	9.40E+00	r	9.40E+00	c	9.40E+00	r	5.71E-03	r	5.71E-03	c	5.71E-03	r
Oxamyl								2.50E-02	i	2.50E-02	r	2.50E-02	r
Paraquat	C							4.50E-03	i	4.50E-03	r	4.50E-03	r
Parathion	C							6.00E-03	h	6.00E-03	r	6.00E-03	r
PCBs (Polychlorinated Biphenyl)	B2	2.00E+00	i	2.00E+00	r	2.00E+00	r						
Pendimethalin (Prowl)								4.00E-02	i	4.00E-02	r	4.00E-02	r
Pentachlorophenol	B2	1.20E-01	i	1.20E-01	r	1.20E-01	r	3.00E-02	i	3.00E-02	r	3.00E-02	r
Permethrin (Ambush)								5.00E-02	i	5.00E-02	r	5.00E-02	r
Phenanthrene	D												
Phenol	D							6.00E-01	i	6.00E-01	r	6.00E-01	r

APPENDIX C
CONTAMINANT TOXICITY DATA

Chemical Name	Weight of Evidence CLASS	SFo (kg-day/mg)		SFi (kg-day/mg)		SFd (kg-day/mg)		RfDo (mg/kg-day)		RfDI (mg/kg-day)		RfDd (mg/kg-day)	
Phenylphenol	C	1.94E-03	h	1.90E-03	r	1.94E-03	r						
Phosphine								3.00E-04	i	8.57E-05	c	3.00E-04	r
Profluralin								6.00E-03	h	6.00E-03	r	6.00E-03	r
Propachlor (Ramros)	D							1.30E-02	i	1.30E-02	r	1.30E-02	r
Propazine (Miloguard)								2.00E-02	i	2.00E-02	r	2.00E-02	r
n-Propylbenzene								1.00E-02	n	1.00E-02	n	1.00E-02	n
Pyrene	D							3.00E-02	i	3.00E-02	r	3.00E-02	r
Pyridine								1.00E-03	i	1.00E-03	r	1.00E-03	r
RDX		1.10E-01	i	1.10E-01	i	1.10E-01	r	3.00E-03	i	3.00E-03	i	3.00E-03	r
Selenium	D							5.00E-03	i				
Silver	D							5.00E-03	i				
Simazine (Princap)	C	1.20E-01	h	1.20E-01	r	1.20E-01	r	5.00E-03	i	5.00E-03	r	5.00E-03	r
Styrene	C							2.00E-01	i	2.90E-01	c	2.00E-01	r
2,4,5-T as Acid	D							1.00E-02	i	1.00E-02	r	1.00E-02	r
2,3,7,8-TCDD (Dioxin)	B2	1.50E+05	h	1.50E+05	h	1.50E+05	r						
Terbacil (Sinbar)								1.30E-02	i	1.30E-02	r	1.30E-02	r
Terbufos (Counter)								2.50E-05	h	2.50E-05	r	2.50E-05	r
1,1,1,2-Tetrachloroethane	C	2.60E-02	i	2.59E-02	c	2.60E-02	r	3.00E-02	i	3.00E-02	r	3.00E-02	r
1,1,2,2-Tetrachloroethane	C	2.00E-01	i	2.03E-01	c	2.00E-01	r						
Tetrachloroethene (PCE)	C-B2	5.20E-02	n	2.03E-03	n	5.20E-02	r	1.00E-02	i	1.14E-01	n	1.00E-02	r
2,3,4,6-Tetrachlorophenol								3.00E-02	i	3.00E-02	r	3.00E-02	r
Tetryl								1.00E-02	h	1.00E-02	r	1.00E-02	r
Toluene	D							2.00E-01	i	1.10E-01	c	2.00E-01	r
TPH GRO								6.00E-02	h	5.71E-02	c	6.00E-02	r
TPH DRO								3.00E-02	i	3.00E-02	r	3.00E-02	r
Toxaphene	B2	1.10E+00	i	1.12E+00	c	1.10E+00	r						
2,4,5-TP (Silvex)	D							8.00E-03	i	8.00E-03	r	8.00E-03	r
1,2,4-Trichlorobenzene	D							1.00E-02	i	5.70E-02	c	1.00E-02	r
1,1,1-Trichloroethane	D							3.50E-02	n	2.86E-01	n	3.50E-02	r
1,1,2-Trichloroethane	C	5.70E-02	i	5.60E-02	c	5.70E-02	r	4.00E-03	i	4.00E-03	r	4.00E-03	r
Trichloroethene (TCE) (see note below)	B2	1.10E-02	n	6.00E-03	n	1.10E-02	r						
2,4,5-Trichlorophenol								1.00E-01	i	1.00E-01	r	1.00E-01	r
2,4,6-Trichlorophenol	B2	1.10E-02	i	1.09E-02	c	1.10E-02	r						
2(2,4,5-Trichlorophenoxy)propionic acid	D							8.00E-03	i	8.00E-03	r	8.00E-03	r

APPENDIX C
CONTAMINANT TOXICITY DATA

Chemical Name	Weight of Evidence CLASS	SFo (kg-day/mg)		SFi (kg-day/mg)		SFd (kg-day/mg)		RfDo (mg/kg-day)		RfDi (mg/kg-day)		RfDd (mg/kg-day)	
1,2,3-Trichloropropane	B2	7.00E+00	h	7.00E+00	r	7.00E+00	r	6.00E-03	i	6.00E-03	r	6.00E-03	r
Triflualine (Treflan)	C	7.70E-03	i	7.70E-03	r	7.70E-03	r	7.50E-03	i	7.50E-03	r	7.50E-03	r
1,2,4-Trimethylbenzene								5.00E-02	i	1.70E-03	i	5.00E-02	r
1,3,5-Trimethylbenzene								5.00E-02	i	1.70E-03	i	5.00E-02	r
2,4,6-Trinitrotoluene		3.00E-02	i	3.00E-02	i	3.00E-02	r	5.00E-04	i	5.00E-04	i	5.00E-04	r
Vanadium								7.00E-03	h				
Vinyl Chloride	A	1.90E+00	h	3.00E-01	c	1.90E+00	r						
Xylene (mixed)	D							2.00E+00	i			2.00E+00	r
Zinc	D							3.00E-01	i				

SFo = oral slope factor
SFi = inhalation slope factor
SFd = dermal slope factor
RfDo = oral reference dose
RfDi = inhalation reference dose
RfDd = dermal reference dose

i = Integrated Risk Information System (IRIS), EPA, 1997
i2 = Integrated Risk Information System (IRIS), EPA, 2002
h = Health Effects Assessment Summary Tables (HEAST), EPA, 1997
n = National Center for Environmental Assessment (NCEA, formerly ECAO)
r = Route to Route Extrapolation
c = Calculated from Inhalation RfC or Unit Risk
e = other EPA resources as approved by KDHE

Weight of Evidence Groups: A is Human Carcinogen; B is Probable Human Carcinogen (B1-limited evidence of carcinogenicity in humans, B2 sufficient evidence of carcinogenicity in animals with inadequate or lack of evidence in humans); C is Possible Human Carcinogen; D is Not Classifiable as to Human Carcinogenicity.

Toxicity values are not available for acenaphthylene, eradicane, or phenanthrene

At the time of the printing of this document, EPA was reevaluating the toxicity of TCE. Upon completion of EPA's evaluation, the reference doses and slope factors of TCE will change accordingly.

Notes

Modifications to the March 1, 2003 RSK Manual

The last version of the RSK Manual was printed on March 1, 2003. Between printings, KDHE will continually modify the internet version of the RSK Manual. Modifications may include corrections to inaccurate data, development of Tier 2 values for additional contaminants, and incorporation of new chemical-specific characteristics. The information presented below describes modifications to the RSK Manual since March 1, 2003.

* June 16, 2003 - Corrections to the Tier 2 Values for bis(2-ethylhexyl)phthalate

In Appendix A of the RSK Manual, KDHE changed the Ground Water Pathway value for bis(2-ethylhexyl)phthalate to 0.006 mg/L, EPA's current MCL. Correspondingly, the Soil to Ground Water Pathway value changed to 18,000 mg/kg. These changes apply to both residential and non-residential scenarios. The soil pathway numbers remain the same.

* July 7, 2004 - Corrections to the Tier 2 Values for trihalomethanes (THMs)

In Appendix A of the RSK Manual, KDHE changed the Ground Water Pathway values for bromodichloromethane, bromoform, chloroform, and dibromochloromethane to 0.080 mg/L for each contaminant, EPA's current MCL. KDHE modified the Soil to Ground Water Pathway values for these contaminants to the following:

bromodichloromethane	1.21 mg/kg
bromoform	1.72 mg/kg
chloroform	0.96 mg/kg
dibromochloromethane	1.33 mg/kg

These changes apply to both residential and non-residential scenarios. The soil pathway numbers remain the same.

* September 28, 2004 - Corrections to K_p and Tier 2 Values for di-n-octyl phthalate

In Appendix B of the RSK Manual, KDHE corrected the K_p (permeability coefficient) value for di-n-octyl phthalate, changing it to 4.168 cm/hr. To arrive at this new K_p value, KDHE used a log K_{ow} value of 8.06 (EPA Soil Screening Guidance, 1996), a molecular weight of 390.6 (Superfund Chemical Data Matrix), and the EPA equation displayed in footnote "m" of Appendix B.

(continued)

Using the recalculated K_p for di-n-octyl phthalate, KDHE modified the Ground Water Pathway values for this contaminant to the following:

	Residential	Non-Residential
Ground Water Pathway	0.010 mg/L	0.048 mg/L

The Soil to Ground Water Pathway values for di-n-octyl phthalate remain the same, as they are based upon soil saturation. The Soil Pathway values are unaffected by a change in K_p.