APPENDIX G

GUIDELINES FOR ADDRESSING ADDITIVE HEALTH EFFECTS UNDER THE RECAP

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G1.0 GENERAL GUIDELINES FOR ADDRESSING ADDITIVE HEALTH EFFECTS

Risk-based RECAP Standards based on noncarcinogenic health effects shall be adjusted to account for additivity if there are multiple COC present that elicit the same critical effect or have the same target organ/system. The risk-based RS requiring adjustment include: (1) $Soil_{ni}$; (2) $Soil_{ni}$-PEF; (3) $Soil_i$; (4) $Soil_i$-PEF; (5) $Soil_{es}$; (6) GW_1; (7) GW_2; (8) GW_{es}; and (9) GW_{air}. For groundwater, refer to Section G2.0 for additional medium-specific guidelines on adjusting RS for additive health effects. For TPH and lead, refer to Section 3.0 for additional guidelines on adjusting RS for these constituents.

For the derivation of a risk-based RS, a RS is calculated for both carcinogenic and noncarcinogenic health effects and the lower of the two standards is identified as the final risk-based standard. If multiple noncarcinogenic COC are present, then the RS for noncarcinogenic health effects shall be adjusted to account for additive effects prior to comparing it to the carcinogenic RS for the identification of the final risk-based RS.

The **critical effect or target organ/system** identified for addressing additive health effects shall be the critical effect or target organ/system listed as the basis for the RfD and/or RfC in *Integrated Risk Information System* (EPA http://www.epa.gov/iris/) or *Health Effects Assessment Summary Tables* (EPA). The critical effects/target organs for all applicable routes of exposure (ingestion and inhalation) shall be identified. The critical effects/target organs for the COC listed in RECAP Tables 1 - 3 are presented in Table G-1 at the end of this Appendix. Critical effects/target organs are often not available for the RfD issued as provisional values by the EPA's National Center for Environmental Assessment (NCEA). If a critical effect/target organ is not available for a NCEA provisional RfD, then it is not required that the RS based on that provisional RfD be adjusted to account for additive health effects. Provisional RfD used to develop MO-1 RS are footnoted with "E" in Table H-1 of Appendix H of RECAP.

RS that are not risk-based shall not be adjusted to account for additivity. The following RS do not require modification to account for additivity: (1) $Soil_{GW}$ (Note: If the groundwater zone to be protected is currently being used as a drinking water source, then the $Soil_{GW}$ shall be modified to account for additivity.); (2) $Soil_{sat}$; (3) GW_3; (4) $Water_{sol}$; (5) a RS based on an approved quantitation limit; (6) a RS based on an approved background concentration; (7) a RS based on the 10,000 mg/kg upper limit for TPH (refer to Section G3.3); (8) RS for lead (refer to Section G3.2); and (9) a groundwater RS based on an MCL (unless there is actual exposure to COC via groundwater) (refer to Section G2.1).

G2.0 MEDIUM-SPECIFIC GUIDELINES FOR ADDRESSING ADDITIVE HEALTH EFFECTS

G2.1 Groundwater

A GW_1 or GW_2 RS based on a MCL (SDWA) shall not be adjusted to account for additivity unless there is actual exposure to multiple COC via groundwater (i.e., the groundwater is currently being used as a drinking water source). If there is actual exposure to impacted groundwater from an aquifer that meets the definition of Groundwater Classifications 1 or 2, then risk-based RS which account for additivity shall be developed for each COC in accordance with Appendix H. When adjusting the GW_1 or GW_2 to account for additivity, the critical effect/target organ shall be identified for all COC (even those COC for which the MCL serves as the GW_1 or GW_2) whether or not actual exposure to groundwater is occurring.

G2.2 C_{ani} and C_{ai} for GW_{es}, GW_{air}, and $Soil_{es}$

If a GW_{es}, GW_{air}, or $Soil_{es}$ is based on a C_{ani} or C_{ai} that is based on a Louisiana Toxic Air Pollutant Ambient Air Standard eight-hour average or annual average (LAC 33:III.5112) and multiple COC are present, a GW_{es}, GW_{air}, or $Soil_{es}$ shall be calculated for each COC (in accordance with Section H2.3 of Appendix H) based on a C_{ani} or C_{ai} that has been adjusted to account for additive health effects.

G3.0 OTHER CONSIDERATIONS REGARDING ADDITIVE HEALTH EFFECTS

G3.1 Multiple AOI

If there are multiple AOI in close proximity and/or receptor activity patterns involve more than one AOI, then the RS shall be adjusted to account for additive health effects associated with COC present at or originating from all AOI contributing to exposure.

G3.2 Lead

Based on lead's mechanism of toxicity, EPA considers it inappropriate to develop a RfD for lead. Risk-based standards for lead are developed using toxicokinetic models based on acceptable blood lead levels in sensitive receptor populations. Therefore, the risk-based RS for lead is not generally adjusted to account for additive health effects.

G3.3 Total Petroleum Hydrocarbons

10,000 ppm cap. A RS of 10,000 ppm for TPH shall not be adjusted to account for additive health effects. If there is potential for additive health effects, the **risk-based** RS for a TPH fraction or mixture shall be adjusted to account for additivity and then compared to the 10,000 ppm cap. If the adjusted risk-based value is less than 10,000 ppm, then the risk-based value shall serve as the risk-based standard. If the adjusted risk-based value is greater than 10,000 ppm, then the upper limit of 10,000 ppm shall be used as the RS.

TPH Fractions. Each fraction may be treated as an individual COC when accounting for additivity, however, in some situations, this approach may be overly conservative. The RfD for aliphatics $C_{>8}$-C_{16} is based on a mixture of aliphatic hydrocarbons ranging from C_8 to C_{16}. Therefore additivity was inherently accounted for during the toxicity testing and RfD development for the $C_{>8}$-C_{10}, $C_{>10}$-C_{12}, and $C_{>12}$-C_{16} fractions. The same is true for the aromatic factions $C_{>8}$-C_{10}, $C_{>10}$-C_{12}, and $C_{>12}$-C_{16}. When accounting for additivity for the TPH fractions, the following fractions should be treated as individual COC: aliphatics $C_{>6}$-C_8, aliphatics $C_{>8}$-C_{16}, aliphatics $C_{>16}$-C_{35}, aromatics $C_{>8}$-C_{16}, and aromatics $C_{>16}$-C_{35} (refer to soil example 5). Refer to Appendix D, Table D-3 for the critical effects/target organs for the TPH fractions.

G4.0 SCREENING STANDARDS

For **carcinogens**, the Department-derived SS have been calculated based on a target risk level of 10^{-6}. For **noncarcinogens**, SS have been calculated based on a hazard quotient of 0.1 to account for potential additive effects associated with the presence of multiple (10) noncarcinogenic COC (having the same critical effect) at the AOI. **SS do not have to be adjusted to account for additivity.**

G5.0 MO-1 AND MO-2 RECAP STANDARDS

For **carcinogens**, the MO-1 and MO-2 RS are based on a target risk level of 10^{-6} in accordance with EPA guidelines and policy (*Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual Part B Development of Risk-Based Preliminary Remediation Goals,* EPA 1991*; Soil Screening Guidance,* EPA 1996*; Role of Baseline Risk Assessment in Superfund Remedy Selection Decisions,* EPA 1991; NCP 40 CFR 300.430(e)(2); *Risk-based Concentration Tables,* EPA Region III; *Preliminary Remediation Goals* EPA Region IX, EPA Region IV; EPA Region VI; and EPA Region VIII). For carcinogens, it is assumed that setting a 10^{-6} risk level for individual constituents and media will generally lead to cumulative risks within the 10^{-4} to 10^{-6} risk range (*Soil Screening Guidance*, EPA 1996). Therefore, since a target risk level of 10^{-6} was used in the development of MO-1 and MO-2 RS, it is generally not necessary to adjust RS that are based on carcinogenic health effects when there is exposure to multiple carcinogens or exposure via multiple media/pathways (RS based on carcinogenic health effects are footnoted with "C" in Tables 2 and 3).

For **noncarcinogens**, the MO-1 and MO-2 RS are based on a target hazard quotient of 1.0 in accordance with EPA guidelines (*Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual*, *Part B - Development of Risk-Based Preliminary Remediation Goals,* EPA 1991*; Soil Screening Guidance,* EPA 1996). A hazard quotient of 1.0 corresponds to an acceptable exposure level for exposure to a single constituent via a single medium. The MO-1 and MO-2 risk-based RS, therefore, represent acceptable exposure levels for exposure to a single constituent via a single medium.

The application of MO-1 or MO-2 risk-based RS at a site where multiple constituents are present that have the same critical health effect could result in cumulative exposure that exceeds a hazard index of 1.0 for that effect. To address this concern, the MO-1 and MO-2 risk-based RS for constituents that produce the same noncarcinogenic critical effect shall be modified to account for potential additive health effects associated with exposure to multiple constituents. To identify the risk-based RS requiring modification, the noncarcinogenic COC for the Option currently being implemented shall be grouped according to the critical effect. If more than one noncarcinogenic COC has the same critical effect, the risk-based RS for those COC shall be divided by the number of COC present in the group (*Soil Screening Guidance: User's Guide*, EPA 1996) (refer to the examples provided below).

As an alternative to modifying the RS based on the number of constituents affecting the same critical effect or target organ/system, the MO-2 RS may be modified to account for additive exposures by apportioning the Hazard Index (equal to 1.0) based on site-specific conditions.

In addition, under MO-2, a total hazard index may be calculated to demonstrate that the total hazard index for a given critical effect or target organ/system is less than or equal to 1.0:

Hazard Index = $[(EC_1/RS_1) + (EC_2/RS_2) + \ldots + (EC_i/RS_i)$

where:

EC_i = exposure concentration for the i^{th} COC; and
RS_i = MO-2 limiting RECAP Standard for the i^{th} constituent

If the Hazard Index for a critical effect or target organ/system is > 1.0 under MO-2, then the AOI shall be evaluated further under MO-3 or remediated to MO-2 RS that have been adjusted to account for additive health effects.

The application of MO-2 RS at a site where a receptor is exposed to a COC(s) by more than one medium [e.g., exposure to soil **and** groundwater such as a residential receptor exposed to both impacted soil and impacted drinking water (groundwater meeting the definition of Groundwater Classification 1 and 2)] could result in a hazard index greater than 1.0 for that COC. To modify a RS to account for exposure to a COC via more than one medium, the MO-2 RS for that COC shall be divided by the number of media that contain the COC and to which the receptor is exposed.

As an alternative to modifying the MO-2 RS to account for additive exposures due to multiple media by dividing by the number of media, the MO-2 RS may be apportioned based on site-specific conditions.

Refer below for examples on adjusting MO-1 and MO-2 risk-based RS to account for additivity:

Examples for exposure to multiple constituents:

Soil Example 1

If acetone, styrene, phenol, and chlorobenzene are present in soil, the $Soil_{ni}$ or $Soil_i$ shall be adjusted to account for cumulative effects as follows:

(1) Identify the critical effect or target organs/systems and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For acetone, the target organs/systems include the liver and kidney. For styrene, the target organs/systems include the liver, central nervous system and hematological system. For phenol, the critical effect is decreased weight gain. For chlorobenzene, the target organ/system is the liver.

(2) Summarize by critical effect or target organ/system:

Kidney: acetone
Liver: acetone, styrene, chlorobenzene
CNS: styrene
Hematological system: styrene
Decreased weight gain: phenol

(3) Adjust the $Soil_{ni}$ or $Soil_i$ to account for cumulative effects for each target organ/system:

The $Soil_{ni}$ or $Soil_i$ for acetone, styrene and chlorobenzene should be divided by 3 to account for cumulative effects to the liver due to simultaneous exposure to acetone, styrene and chlorobenzene.

The $Soil_{ni}$ or $Soil_i$ for phenol should be used as it appears in Table 2 since no other constituents present in the soil cause decreased weight gain.

Soil Example 2

If fluoranthene, pyrene, acenaphthene, 2,4-dimethylphenol, cyanide, phenol, 2,4-dichlorophenol, and 2,4,5-trichlorophenol are present in soil, the $Soil_{ni}$ or $Soil_i$ should be adjusted to account for cumulative effects as follows:

(1) Identify the critical effect or target organs/systems and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For fluoranthene, the target organs/systems include the liver, kidney and hematological system. For pyrene the target organ/system is the kidney. For acenaphthene, the target organ/system is the liver. For 2,4-dimethylphenol, the target organs/systems include the central nervous system (CNS) and the hematological system. For cyanide, the critical effect/target organs/systems include weight loss, the thyroid gland, and CNS. For phenol, the critical effect is decreased weight gain. For 2,4-dichlorophenol, the target organ/system is the immune system. For 2,4,5-trichlorophenol, the target organs/systems include the liver and kidney.

(2) Summarize by critical effect or target organ/system:

Kidney: fluoranthene, pyrene and 2,4,5-trichlorophenol
Liver: fluoranthene, acenaphthene and 2,4,5-trichlorophenol
CNS: 2,4-dimethylphenol and cyanide
Hematological System: fluoranthene and 2,4-dimethylphenol
Decreased weight gain/weight loss: phenol and cyanide
Immune System: 2,4-dichlorophenol
Thyroid gland: cyanide

(3) Adjust the $Soil_{ni}$ or $Soil_i$ to account for cumulative effects for each critical effect or target organ/system:

The $Soil_{ni}$ or $Soil_i$ for fluoranthene, pyrene, acenaphthene, and 2,4,5-trichlorophenol should be divided by 3 to account for cumulative effects to the kidney due to simultaneous exposure to fluoranthene, pyrene and 2,4,5-trichlorophenol and to account for cumulative effects to the liver due to simultaneous exposure to fluoranthene, acenaphthene, and 2,4,5-trichlorophenol.

The soil RS for 2,4-dimethylphenol, phenol, and cyanide should be divided by 2 to account for cumulative effects to the CNS due to simultaneous exposure to 2,4-dimethylphenol and cyanide; to account for cumulative effects to the hematological system due to simultaneous exposure to fluoranthene and 2,4-dimethylphenol; and to account for cumulative effects associated with decreased weight gain/weight loss due to simultaneous exposure to phenol and cyanide.

The $Soil_{ni}$ or $Soil_i$ for 2,4-dichlorophenol should be used as it appears in Table 2 since no other constituents present in the soil affect the immune system.

Soil Example 3

If xylene, styrene, endrin and endosulfan are present in subsurface soil beneath an enclosed-space, the $Soil_{es}$ (MO-2) should be adjusted to account for additive effects as follows:

(1) Identify the critical effect or target organs/systems and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For xylene, the target organ/system is the CNS. For styrene, the target organs/systems include the liver, CNS, and the hematological system. For endrin, the target organs/systems include the liver and CNS. For endosulfan, the target organ/system is the kidney.

(2) Summarize by critical effect or target organ/system:

CNS: xylene, styrene, endrin
Liver: styrene, endrin

Hematological System: styrene
Kidney: endosulfan

(3) Adjust the $Soil_{es}$ to account for cumulative effects for each critical effect or target organ/system:

The $Soil_{es}$ for xylene and styrene should be divided by 2 to account for cumulative effects to the CNS due to simultaneous inhalation exposure to xylene and styrene.

The $Soil_{es}$ for endrin and endosulfan should not be considered since they are not volatile and not of concern for this pathway.

Soil Example 4

If toluene, ethylbenzene, xylene (TEX), aliphatics $C_{>6}$-C_8, aliphatics $C_{>8}$-C_{12}, and aromatics $C_{>8}$-C_{12}, are present in soil, the $Soil_{ni}$ or $Soil_i$ shall be adjusted to account for cumulative effects as follows:

(1) Identify the critical effect or target organs/systems (IRIS or HEAST and Appendix H) and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For toluene, the target organs/systems include the liver, CNS, nasal epithelium, and kidney. For ethylbenzene, the target organs/systems include the liver, kidney, and developmental effects. For xylene, the target organ/system and critical effects are the CNS, increased mortality, and decreased body weight. For aliphatics $C_{>6}$-C_8, the kidney is the target organ/system. For aliphatics $C_{>8}$-C_{12}, the liver and hematological system are the target organs/systems. For aromatics $C_{>8}$-C_{12}, decreased body weight is the critical effect.

(2) Summarize by critical effect or target organ/system:

Kidney: toluene, ethylbenzene, aliphatics $C_{>6}$-C_8
Liver: toluene, ethylbenzene, aliphatics $C_{>8}$-C_{12}
CNS: toluene, xylene
Hematological System: aliphatics $C_{>8}$-C_{12}
Body Weight Change: xylene, aromatics $C_{>8}$-C_{12}
Developmental effects: ethylbenzene
Nasal epithelium: toluene
Increased mortality: xylene

(3) Adjust the $Soil_{ni}$ or $Soil_i$ to account for cumulative effects for each critical effect or target organ/system:

The $Soil_{ni}$ or $Soil_i$ for toluene, ethylbenzene, aliphatics $C_{>6}$-C_8, and aliphatics $C_{>8}$-C_{12} should be divided by 3 to account for cumulative effects to the liver due to simultaneous exposure to toluene, ethylbenzene and aliphatics $C_{>8}$-C_{12} and for cumulative effects to the kidney due to simultaneous exposure to toluene, aliphatics $C_{>6}$-C_8, and ethylbenzene.

The $Soil_{ni}$ or $Soil_i$ for xylene and aromatics $C_{>8}$-C_{12} should be divided by 2 to account for cumulative effects on body weight and for cumulative effects to the CNS due to simultaneous exposure to toluene and xylene.

The $Soil_{ni}$ or $Soil_i$ for aliphatics $C_{>8}$-C_{12} should be used as it appears in Table 2 since no other constituents present in the soil affect the hematologic system.

Soil Example 5

If ethylbenzene, aliphatics $C_{>8}$-C_{10}, aliphatics $C_{>10}$-C_{12}, and aliphatics $C_{>12}$-C_{16}, are present in soil, the $Soil_{ni}$ or $Soil_i$ shall be adjusted to account for cumulative effects as follows:

(1) Identify the critical effect or target organs/systems (IRIS or HEAST and Appendix D) and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For ethylbenzene, the target organs/systems include the liver, kidney, and developmental effects. For aliphatics $C_{>8}$-C_{16}, the liver and hematological system are the target organs/systems.

(2) Summarize by critical effect or target organ/system:

Liver: ethylbenzene, aliphatics $C_{>8}$-C_{16}
Kidney: ethylbenzene
Hematological System: aliphatics $C_{>8}$-C_{16}
Developmental effects: ethylbenzene

(3) Adjust the $Soil_{ni}$ or $Soil_i$ to account for cumulative effects for each critical effect or target organ/system:

The $Soil_{ni}$ or $Soil_i$ for ethylbenzene and aliphatics $C_{>8}$-C_{10}, aliphatics $C_{>10}$-C_{12} and aliphatics $C_{>12}$-C_{16} should be divided by 2 to account for cumulative effects to the liver due to simultaneous exposure to ethylbenzene and aliphatics $C_{>8}$-C_{16}.

Groundwater Example 1

If acetone, chlorobenzene, endrin, fluoranthene, and butylbenzylphthalate are present in groundwater meeting the definition of Groundwater Classification 1 or 2 but no exposure

points are present and no exposure to impacted groundwater is occurring, the groundwater RS (GW_1 and GW_2) should be adjusted to account for cumulative effects as follows:

(1) Identify the critical effect or target organs/systems and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For acetone, the target organs/systems include the liver and kidney. For chlorobenzene, the target organ/system is the liver. For endrin, the target organs/systems include the liver and CNS. For fluoranthene, the target organs/systems include the liver, kidney, and hematological system. For butylbenzylphthalate, the target organs/systems are the liver and the CNS.

(2) Summarize by critical effect or target organ/system:

Liver: acetone, chlorobenzene, endrin, fluoranthene, and butylbenzylphthalate
Kidney: acetone and fluoranthene
CNS: endrin and butylbenylphthalate
Hematological System: fluoranthene

(3) Adjust the GW_1 and GW_2 to account for cumulative effects for each critical effect or target organ/system:

The GW_1 and GW_2 for acetone, fluoranthene, and butylbenzylphthalate should be divided by 5 to account for cumulative effects to the liver due to simultaneous exposure to acetone, chlorobenzene, endrin, fluoranthene, and butylbenzylphthalate (this also accounts for cumulative effects to the kidney due to simultaneous exposure to acetone and fluoranthene and cumulative effects to the CNS due to simultaneous exposure to endrin and butylbenzylphthalate).

The GW_1 and GW_2 for chlorobenzene and endrin are based on the MCL and since no exposure points are present and no exposure to impacted groundwater is occurring, the groundwater RS (MCL) should be used as presented in Table 3.

Groundwater Example 2

If fluoranthene, pyrene, acenaphthene, 2,4-dimethylphenol, cyanide, phenol, 2,4-dichlorophenol and 2,4,5-trichlorophenol are present in groundwater meeting the definition of Groundwater Classification 1 or 2 **and** an exposure point has been identified (i.e., exposure is occurring), the GW_1 and GW_2 should be adjusted to account for cumulative effects as follows:

(1) Identify the target organs/systems and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For fluoranthene, the target organs/systems include the liver, kidney and hematological system. For pyrene the target organ/system is the kidney. For acenaphthene, the target organ/system is the liver. For 2,4-dimethylphenol, the critical effects/target organs/systems include the hematological system and clinical toxicity. For cyanide, the critical effects/target organs/systems are the CNS, the thyroid gland, and weight loss. For phenol, the critical effect is decreased weight gain. For 2,4-dichlorophenol, the target organ/system is the immune system. For 2,4,5-trichlorophenol, the target organs/systems include the liver and kidney.

(2) Summarize by critical effect or target organ/system:

Kidney: fluoranthene, pyrene and 2,4,5-trichlorophenol
Liver: fluoranthene, acenaphthene and 2,4,5-trichlorophenol
CNS: cyanide
Hematological System: fluoranthene and 2,4-dimethylphenol
Decreased weight gain/weight loss: cyanide and phenol
Immune System: 2,4-dichlorophenol
Clinical toxicity: 2,4-dimethylphenol
Thyroid gland: cyanide

(3) Adjust the GW_1 and GW_2 to account for cumulative effects for critical effect or target organ/system:

The GW_1 and GW_2 for fluoranthene, pyrene, acenaphthene, and 2,4,5-trichlorophenol should be divided by 3 to account for cumulative effects to the kidney due to simultaneous exposure to fluoranthene, pyrene and 2,4,5-trichlorophenol and to account for cumulative effects to the liver due to simultaneous exposure to fluoranthene, acenaphthene, and 2,4,5-trichlorophenol.

The GW_1 and GW_2 for 2,4-dimethylphenol, phenol, and cyanide should be divided by 2 to account for cumulative effects to the hematological system due to simultaneous exposure to fluoranthene and 2,4-dimethylphenol and to account for cumulative effects associated with decreased weight gain/weight loss due to simultaneous exposure to phenol and cyanide.

The GW_1 and GW_2 for 2,4-dichlorophenol should be used as they appear in Table 3 since no other constituents present in the groundwater affect the immune system.

A GW_1 or GW_2 for cyanide should be developed to account for additive effects since: (1) the GW_1/ GW_2 is based on the MCL, (2) there is actual exposure to the groundwater, and (3) there is more than one constituent in the groundwater that elicits noncarcinogenic effects on the CNS.

Groundwater Example 3

If nitrobenzene, 2,4,5-trichlorophenol and barium are present in groundwater meeting the definition of Groundwater Classification 3, the GW_3 should be used as it appears in Table 3. The GW_3 RS is based on the prevention of cross-media transfer (i.e., groundwater discharge to surface water). Therefore, these RS are not adjusted to account for additivity.

Groundwater Example 4

If acetone, styrene, endrin, and chlorobenzene are present in groundwater located beneath an enclosed-space, the GW_{es} should be adjusted to account for cumulative effects as follows:

(1) Identify the critical effect or target organs/systems and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For acetone, the target organs/systems include the liver and kidney. For endrin, the target organs/systems include the liver and CNS. For phenol, the critical effect is decreased weight gain. For chlorobenzene, the target organ/system is the liver.

(2) Summarize by critical effect or target organ/system:

Kidney: acetone
Liver: acetone, endrin, chlorobenzene
CNS: endrin
Decreased weight gain: phenol

(3) Adjust the GW_{es} to account for cumulative effects for each critical effect or target organ/system:

The GW_{es} for acetone and chlorobenzene should be divided by 2 to account for cumulative effects to the liver due to simultaneous exposure to acetone and chlorobenzene.

The GW_{es} for phenol should be used as it appears in Table 3 or as calculated under MO-2 since no other constituents present in the groundwater cause decreased weight gain.

Endrin should not be considered for this pathway because it is not volatile.

Groundwater Example 5

If toluene, ethylbenzene, xylene (TEX), aliphatics $C_{>6}$-C_8, aliphatics $C_{>8}$-C_{12}, and aromatics $C_{>8}$-C_{12} are present in groundwater meeting the definition of Groundwater

Classification 1 or 2 but no exposure points are present and no exposure to impacted groundwater is occurring, the groundwater RS (GW_1 and GW_2) should be adjusted to account for cumulative effects as follows:

(1) Identify the critical effect or target organs/systems (IRIS or HEAST) and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For toluene, the target organs/systems include the liver, nasal epithelium, CNS, and kidney. For ethylbenzene, the target organs/systems include the liver, kidney, and developmental effects. For xylene, the target organ and critical effects include the CNS, increased mortality, and decreased body weight. For aliphatics $C_{>6}$-C_8, the kidney is the target organ/system. For aliphatics $C_{>8}$-C_{12}, the liver and hematologic system are the target organs/systems. For aromatics $C_{>8}$-C_{12}, decreased body weight is the critical effect.

(2) Summarize by critical effect or target organ/system:

Kidney: toluene, ethylbenzene, aliphatics $C_{>6}$-C_8
Liver: toluene, ethylbenzene, aliphatics $C_{>8}$-C_{12}
CNS: toluene, xyleneHematologic System: aliphatics $C_{>8}$-C_{12}
Body Weight Change: xylene, aromatics $C_{>8}$-C_{12}
Developmental effects: ethylbenzene
Nasal epithelium: toluene
Increased mortality: xylene

(3) Adjust the GW_1 and GW_2 to account for cumulative effects for each critical effect or target organ/system:

The GW_1 and GW_2 for ethylbenzene, toluene and xylene are based on the MCL and since no exposure points are present and no exposure to impacted groundwater is occurring, the groundwater RS (MCLs) should be used as presented in Table 3.

The GW_1 and GW_2 for aliphatics $C_{>6}$-C_8 and aliphatics $C_{>8}$-C_{12} should be divided by 3 to account for cumulative effects to the liver due to simultaneous exposure to toluene, ethylbenzene, and aliphatics $C_{>8}$-C_{12} and to account for cumulative effects to the kidney due to simultaneous exposure to toluene, ethylbenzene, and aliphatics $C_{>6}$-C_{10}.

The GW_1 and GW_2 for aromatics $C_{>8}$-C_{12} should be divided by 2 to account for cumulative effects on body weight due to simultaneous exposure to xylene and aromatics $C_{>8}$-C_{12}.

Example for exposure to more than one medium:

- toluene, ethylbenzene and xylene are present in the soil;

- toluene and xylene are present in groundwater meeting the definition of Groundwater Classification 1 or 2; and

- the receptor is being exposed to both impacted soil and impacted groundwater meeting the definition of Groundwater Classification 1 or 2 [an exposure point has been identified (a water supply well) and exposure is occurring].

(1) **Adjust for exposure to multiple constituents**

(a) Identify the critical effect or target organs/systems (IRIS or HEAST) and group the constituents according to the critical effect or target organ/system on which the RfD (RfC) is based.

For toluene, the target organs/systems include the liver, nasal epithelium, CNS, and kidney. For ethylbenzene, the target organs/systems include the liver, kidney, and developmental effects. For xylene, the target organ and critical effects include the CNS, increased mortality, and decreased body weight.

(b) Summarize by critical effect or target organ/system:

Kidney: toluene, ethylbenzene
Liver: toluene, ethylbenzene
CNS: toluene, xylene
Body Weight Change: xylene
Developmental effects: ethylbenzene
Nasal epithelium: toluene
Increased mortality: xylene

(c) Adjust the RS to account for cumulative effects for each critical effect or target organ/system:

The $Soil_{ni}$ or $Soil_i$ for toluene, ethylbenzene should be divided by 2 to account for cumulative effects to the liver and the kidney due to simultaneous exposure to toluene and ethylbenzene.

The $Soil_{ni}$ or $Soil_i$ for xylene should be divided by 2 to account for cumulative effects to the CNS due to simultaneous exposure to xylene and toluene.

The GW_1 or GW_2 for toluene and xylene should be divided by 2 to account for cumulative effects to the CNS due to simultaneous exposure to xylene and toluene.

(2) **Adjust for exposure to more than one medium**

The $Soil_i$ or $Soil_{ni}$, for toluene and xylene should be adjusted to account for cumulative effects by dividing the RS identified in Step 1.c by 2.

The GW_1 or GW_2 for toluene and xylene should be adjusted to account for cumulative effects by dividing the RS identified in Step 1.c by 2.

Example of calculating a Hazard Index using RS:

Acetone (300 mg/kg), styrene (420 mg/kg), phenol 30,000 (mg/kg), and chlorobenzene (31 mg/kg) were detected in soil at an industrial site. The MO-2 $Soil_i$ RS are 1400 mg/kg for acetone, 1700 mg/kg for styrene, 24,000 mg/kg for phenol, and 120 mg/kg for chlorobenzene. Identification of the critical effects/target organs indicates that acetone, styrene, and chlorobenzene all elicit noncarcinogenic effects on the liver.

Hazard Index = $[(EC_1/RS_1) + (EC_2/RS_2) + \ldots + (EC_i/RS_i)$

where:
EC_i = exposure concentration for the i^{th} COC; and
RS_i = MO-2 limiting RECAP Standard for the i^{th} constituent

The Hazard Index for the liver (acetone, styrene, and chlorobenzene) = 300/1400 + 420/1700 + 31/120 = 0.72. The Hazard Index for the liver is 0.72 which is less than 1.0, therefore, no further action is warranted at this time for these constituents.

The Hazard Index for phenol = 30,000/24,000 = 1.25. The Hazard Index for phenol is 1.25 which is greater than 1.0, therefore, this COC shall be further evaluated under MO-3 or remediated to the MO-2 RS.

G6.0 MO-3 RECAP STANDARDS

For **carcinogens**, it is assumed that the development of site-specific RS based on a target risk level o 10^{-6} for individual constituents will generally lead to a cumulative cancer risk within the acceptable risk range of 10^{-6} to 10^{-4} (*Soil Screening Guidance*, EPA 1996). Therefore, a target risk level of 10^{-6} shall be used in the development of MO-3 RS unless otherwise approved by the Department. Refer to Section 2.14 for further information on acceptable cancer risk levels under MO-3.

For **noncarcinogens,** the target hazard index of 1.0 shall be apportioned to account for additive health effects based on site-specific conditions. The target hazard index (or RS) shall be modified to account for additive health effects associated with: 1) exposure to more than one constituent that has the same critical effect as defined by the RfD and/or RfC; 2) exposure to more than one environmental medium that contains the same COC; 3) exposure via multiple pathways; and/or 4) exposure to constituents present at one or more AOI (if appropriate based on the proximity of multiple AOI, the COC/exposure pathways present, and/or receptor activity patterns).

TABLE G-1
Critical Effects and Target Organs/Systems [1]

CONSTITUENT	CAS #	CRITICAL EFFECT(S)/TARGET ORGAN(S) [2]
Acenaphthene	83-32-9	Liver toxicity
Acetone	67-64-1	Liver effects (increased weight); Kidney toxicity
Aldrin	309-00-2	Liver toxicity
Aniline	62-53-3	Spleen toxicity
Anthracene	120-12-7	No observed effects
Antimony	7440-36-0	Decreased longevity; Decreased blood glucose; Altered blood cholesterol levels
Arsenic	7440-38-2	Skin effects (hyperpigmentation and keratosis); Vascular effects
Barium	7440-39-3	Kidney effects (increased weight)
Benzene	71-43-2	Bone marrow toxicity (lymphocytopenia) [3]
Benz(a)anthracene	56-55-3	NA [4]
Benzo(a)pyrene	50-32-8	NA
Benzo(b)fluoranthene	205-99-2	NA
Benzo(k)fluoranthene	207-08-9	NA
Beryllium	7440-41-7	Gastrointestinal effects (erosion and inflammatory lesions); Beryllium sensitization; Respiratory system (chronic beryllium disease - chronic inflammatory lung disease)
Biphenyl,1,1-	92-52-4	Kidney toxicity
Bis(2-chloroethyl)ether	111-44-4	NA
Bis(2-chloroisopropyl)ether	108-60-1	Hematological system effects (red blood cell toxicity/destruction and decreased hemoglobin)
Bis(2-ethyl-hexyl)phthalate	117-81-7	Liver effects (increased weight)
Bromodichloromethane	75-27-4	Kidney effects (cytomegaly)
Bromoform	75-25-2	Liver effects
Bromomethane	74-83-9	Gastrointestinal effects (epithelial hyperplasia of stomach); Nasal cavity effects (degeneration and proliferative lesions of the olfactory epithelium)
Butyl benzyl phthalate	85-68-7	Liver effects (increased weight); CNS effects (increased brain weight)
Cadmium	7440-43-9	Kidney effects (proteinuria)
Carbon Disulfide	75-15-0	Fetal toxicity (malformations); Peripheral nervous system dysfunction
Carbon Tetrachloride	56-23-5	Liver toxicity
Chlordane	57-74-9	Liver toxicity (necrosis)
Chloroaniline,p-	106-47-8	Spleen effects (capsular lesions)
Chlorobenzene	108-90-7	Liver effects
Chlorodibromomethane	124-48-1	Liver effects
Chloroethane (Ethylchloride)	75-00-3	Fetal toxicity (delayed ossification)
Chloroform	67-66-3	Liver effects (fatty cyst formation; increased SGPT)
Chloromethane (Methyl chloride)	74-87-3	CNS (cerebellar lesions)
Chloronaphthalene,2-	91-58-7	Liver (increased weight); Respiratory effects (dyspnea)
Chlorophenol,2-	95-57-8	Reproductive effects (increased conceptions, increased stillbirths, decreased litter size)
Chromium(III)	16065-83-1	No observed effects
Chromium(VI)	18540-29-97	Aerosols: Nasal cavity effects (septum atrophy); Dusts: Lower respiratory system toxicity
Chrysene	218-01-9	NA
Cobalt	7440-48-4	NA

CONSTITUENT	CAS #	CRITICAL EFFECT(S)/TARGET ORGAN(S) [2]
Copper	7440-50-8	Gastrointestinal effects (irritation)
Cyanide (free)	57-12-5	Weight loss; Thyroid gland effects; Nervous system effects (myelin degeneration)
DDD	72-54-8	NA
DDE	72-55-9	NA
DDT	50-29-3	Liver effects
Dibenz(a,h)anthracene	53-70-3	NA
Dibenzofuran	132-64-9	NA
Dibromo-3-chloropropane,1,2-	96-12-8	Reproductive system effects (decreased sperm count and decreased number of live sperm)
Dichlorobenzene,1,2-	95-50-1	No observed effects
Dichlorobenzene,1,3-	541-73-1	NA
Dichlorobenzene,1,4-	106-46-7	Liver effects (increased weight)
Dichlorobenzidine,3,3-	91-94-1	NA
Dichloroethane,1,1-	75-34-3	No observed effects
Dichloroethane,1,2-	107-06-2	NA
Dichloroethene ,1,1-	75-35-4	Liver toxicity (fatty change)
Dichloroethene,cis,1,2-	156-59-2	Hematological effects (decreased hemoglobin and hematocrit)
Dichloroethene,trans,1,2-	156-60-5	Liver effects (increased serum alkaline phosphatase)
Dichlorophenol,2,4-	120-83-2	Immune system effects (altered immune function)
Dichloropropane,1,2-	78-87-5	Nasal cavity effects (epithelial hyperplasia)
Dichloropropene,1,3-	542-75-6	Gastrointestinal effects (irritation); Nasal cavity effects (hyperplasia and hypertrophy of epithelium)
Dieldrin	60-57-1	Liver effects
Diethylphthalate	84-66-2	Decreased growth rate; Decreased food consumption; Altered organ weights
Dimethylphenol,2,4-	105-67-9	Hematological effects; Clinical signs of toxicity (lethargy, ataxia, and prostration)
Dimethylphthalate	131-11-3	NA
Di-n-octylphthalate	117-84-0	NA
Dinitrobenzene,1,3-	99-65-0	Spleen effects (increased weight)
Dinitrophenol,2,4-	51-28-5	Ocular effects (cataract formation)
Dinitrotoluene,2,6-	606-20-2	Central nervous system effects; Hematological effects; Biliary system effects; Kidney effects; Decreased longevity
Dinitrotoluene,2,4-	121-14-2	Central nervous system toxicity; Biliary system effects; Hematological system effects
Dinoseb	88-85-7	Fetal effects (decreased weight)
Endosulfan	115-29-7	Decreased growth rate; Kidney effects (glomerulonephrosis); Vascular system effects (aneurysms)
Endrin	72-20-8	Liver effects; Central nervous system effects (stimulation/convulsions)
Ethyl benzene	100-41-4	Liver toxicity; Kidney toxicity; Fetal effects (skeletal abnormalities)
Fluoranthene	206-44-0	Kidney effects; Liver effects; Hematological effects
Fluorene	86-73-7	Hematological effects
Heptachlor	76-44-8	Liver effects
Heptachlor epoxide	1024-57-3	Liver effects
Hexachlorobenzene	118-74-1	Liver effects
Hexachlorobutadiene	87-68-3	Kidney effects
Hexachlorocyclohexane,alpha	319-84-6	NA
Hexachlorocyclohexane,beta	319-85-7	NA

CONSTITUENT	CAS #	CRITICAL EFFECT(S)/TARGET ORGAN(S) [2]
Hexachlorocyclohexane,gamma	58-89-9	Liver effects; Kidney effects
Hexachlorocyclopentadiene	77-47-4	Gastrointestinal effects (chronic irritation); Suppurative inflammation of nose
Hexachloroethane	67-72-1	Kidney effects
Indeno(1,2,3-cd)pyrene	193-39-5	NA
Isobutyl alcohol	78-83-1	Central nervous system effects (hypoactivity and ataxia)
Isophorone	78-59-1	Kidney effects
Lead (inorganic)	7439-92-1	NA
Mercury (inorganic)	7439-97-6	Central nervous system effects
Methoxychlor	72-43-5	Reproductive effects (increased loss of litters)
Methylene chloride	75-09-2	Liver effects
Methyl ethyl ketone	78-93-3	Fetal effects (decreased birth weight)
Methyl isobutyl ketone	108-10-1	Fetal effects (decreased body weight, skeletal effects, increased mortality)
MTBE (methyl tert-butyl ether)	1634-04-4	Liver effects (increased weight); Kidney (increased weight); Ocular effects (swelling of periocular tissues)
Naphthalene	91-20-3	Decreased body weight; Nasal cavity effects (epithelial hyperplasia and olfactory epithelial metaplasia)
Nickel	7440-02-0	NA
Nitrate	14797-55-8	Hematological system effects (methemoglobin formation in infants)
Nitrite	14797-65-0	Hematological system effects (methemoglobin formation in infants)
Nitroaniline,2-	88-74-4	Hematological system effects
Nitroaniline,3-	99-09-2	NA
Nitroaniline,4-	100-01-6	NA
Nitrobenzene	98-95-3	Hematological system effects; Adrenal gland effects; Kidney effects; Liver toxicity
Nitrophenol,4-	100-02-7	NA
Nitrosodi-n-propylamine,n-	621-64-7	NA
N-nitrosodiphenylamine	86-30-6	NA
Pentachlorophenol	87-86-5	Liver effects; Kidney effects
Phenol	108-95-2	Decreased weight gain
Polychlorinated biphenyls	1336-36-3	Aroclor 1016: Fetal effects (decrease birth weight) Aroclor 1248: NA Aroclor 1254: Ocular effects; Immune system effects; Integument effects (distorted growth of nails) Aroclor 1260: NA
Pyrene	129-00-0	Kidney effects
Selenium	7782-49-2	Integument effects (hair loss, nail loss, nail abnormalities, skin lesions); Dental effects; Hematological effects (decreased hemoglobin); Central nervous system effects
Silver	7440-22-4	Skin effects (argyria)
Styrene	100-42-5	Hematological system effects (heinz body formation); Liver effects; Central nervous system effects (decreased intellectual function; decreased memory; and decreased reaction time)
Tetrachlorobenzene,1,2,4,5-	95-94-3	Kidney effects
Tetrachloroethane,1,1,1,2-	630-20-6	Kidney effects; Liver effects
Tetrachloroethane,1,1,2,2-	79-34-5	NA
Tetrachloroethylene	127-18-4	Liver effects
Tetrachlorophenol,2,3,4,6-	58-90-2	Liver toxicity
Thallium	7440-28-0	Liver effects
Toluene	108-88-3	Liver effects (change in weight); Kidney effects (change in weight); Central nervous system effects (decreased concentration-

CONSTITUENT	CAS #	CRITICAL EFFECT(S)/TARGET ORGAN(S) [2]
		response relationship); Nasal cavity (degeneration of epithelium)
Toxaphene	8001-35-2	NA
Trichlorobenzene,1,2,4-	120-82-1	Adrenal gland effects; Liver effects (weight change)
Trichloroethane,1,1,1-	71-55-6	NA
Trichloroethane,1,1,2-	79-00-5	Liver effects
Trichloroethene	79-01-6	CNS effects; Liver effects; Endocrine system effects; Kidney effects; Fetal effects [3]
Trichlorofluoromethane	75-69-4	Decreased longevity; Respiratory system effects (pleuritis); Cardiac system effects (pericarditis)
Trichlorophenol,2,4,5-	95-95-4	Liver effects; Kidney effects
Trichlorophenol,2,4,6-	88-06-2	NA
Vanadium	7440-62-2	Increased mortality
Vinyl chloride	75-01-4	Liver effects (cellular polymorphism)
Xylene (mixed)	1330-20-7	Central nervous system effects (impaired motor coordination); Decreased body weight; Decreased longevity
Zinc	7440-66-6	Hematological system effects (decreased erythrocyte superoxide dismutase in red blood cells)
Aliphatics C6-C8	NA	Kidney effects
Aliphatics >C8-C16	NA	Liver effects; Hematological system effects
Aliphatics >C16-C35	NA	Liver effects
Aromatics >C8-C16	NA	Decreased body weight
Aromatics >C16-C35	NA	Kidney effects

[1]Data were obtained from EPA's Integrated Risk Information System and Health Effects Assessment Summary Tables; includes target organs/critical effects for the ingestion and inhalation routes of exposure (where available).

[2]The target organs/critical effects on which the reference dose(s) is based.

[3]NCEA; RAIS June 2003.

[4]Not applicable or not available.