HUMAN HEALTH RISK ASSESSMENT EXECUTIVE SUMMARY

The Housatonic River, its sediment, and associated floodplain have been contaminated with polychlorinated biphenyls (PCBs) and other hazardous substances released from the General Electric Company (GE) facility located in Pittsfield, MA. The entire site, known as the General Electric/Housatonic River Site, consists of the 254-acre (103-hectare) GE manufacturing facility; the Housatonic River and its floodplain from Pittsfield, MA, to Long Island Sound; former river oxbows that have been filled with material originating at the facility; neighboring commercial properties; Allendale School; Silver Lake; and other properties or areas that have become contaminated as a result of GE's facility operations.

PURPOSE OF THE HHRA

In September 1998, after years of scientific investigations and regulatory actions, a comprehensive agreement was reached between GE and various governmental entities, including the U.S. Environmental Protection Agency (EPA), the Massachusetts Department of Environmental Protection (MDEP), the U.S. Department of Justice (DOJ), the Connecticut Department of Environmental Protection (CTDEP), and the City of Pittsfield. The agreement provides for the investigation and cleanup of the Housatonic River and associated areas. The agreement has been documented in a Consent Decree between all parties that was entered by the federal court in October 2000. Under the terms of the Consent Decree, EPA conducted the human health and ecological risk assessments, and is conducting a modeling study of PCB transport and fate for the Housatonic River below the confluence of the East and West Branches ("Rest of River").

The "Rest of River," which is the subject of this risk assessment, is the portion of the river from the confluence of the East and West Branches of the Housatonic River (the confluence) in Pittsfield, to the Massachusetts border with Connecticut, a distance of approximately 54 miles (87 km), and beyond into Connecticut to Long Island Sound. The total distance from the confluence to Long Island Sound is approximately 139 miles (224 km). In addition to the river proper, the Rest of River includes the associated riverbank and floodplain, extending laterally to the 1-part per million (ppm) PCB isopleth. Between the confluence and Woods Pond Dam, the 1-ppm total PCBs (tPCB) isopleth is approximately equivalent to the 10-year floodplain (BBL, 1996).

The Human Health Risk Assessment (HHRA), along with the Ecological Risk Assessment and Modeling Study, represents an important component of EPA's investigation of the Rest of River. This evaluation will be considered in:

- Determining the need for remedial action.
- Setting media protection goals for contaminants of concern.

The HHRA evaluates the current and reasonably anticipated future uses of the Housatonic River, its floodplain, and its environs in the analysis of potential risks. For pathways involving direct and indirect exposure to floodplain soil and sediment, current land use and river use form the basis for the evaluation of existing (i.e., baseline) conditions. Future land and river uses form the basis for the evaluation of risks associated with future use of the site.

ORGANIZATION OF THE HHRA REPORT

The HHRA consists of seven volumes. This volume (Volume I) provides a comprehensive assessment of the potential risks to human health associated with contamination in the Rest of River portion of the GE/Housatonic River Site for all exposure pathways, including those arising from direct contact with soil and sediment, consumption of fish and waterfowl from the river, and consumption of agricultural products (both plant and animal) grown on the floodplain. The six remaining volumes are appendices that provide the details of the assessment conducted for each exposure pathway. They are:

- Appendix A (Volumes IIA and IIB): Phase 1 Direct Contact Screening Risk Assessment.
- Appendix B (Volumes IIIA and IIIB): Phase 2 Direct Contact Risk Assessment.
- Appendix C (Volume IV): Consumption of Fish and Waterfowl Risk Assessment.
- Appendix D (Volume V): Agricultural Product Consumption Risk Assessment.

The HHRA also has nine attachments, presented in this volume, that provide technical details for the statistical approaches used throughout the HHRA (Attachments 1 through 5), the toxicological properties of certain contaminants identified at the site (Attachment 6), chemical analytical methods for PCBs and Aroclors (Attachment 7), historical data review (Attachment 8), and summary of analytical variability (Attachment 9). The risk assessment was performed in accordance with EPA policies and procedures.

This volume describes the site and relevant population in detail, presents the overall approach to the risk assessment and an overview of the available site data, and provides a toxicity assessment of the contaminants that drive the risk. It details screening risk analyses for direct contact with air and surface water, and summarizes the results of a screening risk assessment conducted for direct contact with soil and sediment (the full assessment is in Appendix A). This volume also summarizes risks that were quantified for three pathways by which adults and children may come into contact with contaminants associated with the Rest of River:

- Direct contact with soil and sediment in areas not eliminated from the screening risk assessment.
- Consumption of fish and waterfowl.
- Consumption of agricultural products or wild edible plants grown in the floodplain.

Risks from these pathways were characterized using both point estimate and probabilistic approaches. The final section of this volume provides an integrated characterization of the risks posed by the Housatonic River Site by indicating how risks from multiple exposure pathways and areas should be combined, by comparing exposures from the site to expected background dietary intake, and by comparing concentrations of PCBs in breast milk in population studies to those predicted in Housatonic River Area (HRA) women due to site-related exposures.

SITE DESCRIPTION

The Rest of River encompasses the Housatonic River and its associated floodplain from the confluence of the East and West Branches downstream to Long Island Sound. To simplify the description of the Rest of River evaluation, reaches of the river were designated. The 13 reaches are:

- ***Reach 5*** – From the confluence of the East and West Branches to the Woods Pond headwaters.

- ***Reach 6*** **–** Woods Pond impoundment.
- ***Reach 7*** – From Woods Pond Dam to the upstream extent of the Rising Pond impoundment.
- ***Reach 8*** **–** Rising Pond impoundment.
- ***Reach 9*** **–** From Rising Pond Dam to the Massachusetts/Connecticut border.
- ***Reach 10*** **–** From the Massachusetts/Connecticut border to Great Falls Dam.
- ***Reach 11*** **–** From Great Falls Dam to Cornwall Bridge.
- ***Reach 12*** **–** From Cornwall Bridge to Bulls Bridge Dam.
- ***Reach 13*** **–** From Bulls Bridge Dam to the Bleachery (New Milford) Dam.
- ***Reach 14*** **–** From the Bleachery Dam to Shepaug Dam (Lake Lillinonah).
- ***Reach 15*** **–** From Shepaug Dam to Stevenson Dam (Lake Zoar).
- ***Reach 16*** **–** From Stevenson Dam to Derby Dam (Lake Housatonic).
- ***Reach 17*** **–** From Derby Dam to Long Island Sound.

Reaches 5 and 6 comprise the Primary Study Area (PSA). PCBs have been detected in the highest concentrations and frequencies in the PSA, and consequently, this area has been the most extensively characterized by sampling and ecological evaluations. Floodplain soil in Reach 5 is used for residential, recreational, agricultural, and industrial purposes. Land use around Reach 6 (Woods Pond) is recreational. Floodplain land use in the downstream reaches is mixed use, similar to Reach 5. The river is used for recreational purposes, including boating and fishing, in all reaches. There is no commercial fishery in the Housatonic River, nor is the river known to be a drinking water supply.

HAZARD IDENTIFICATION

The purpose of the hazard identification is to identify the data available to assess risks, to summarize the data relevant to human health, to identify contaminants of potential concern (COPCs), and to develop a conceptual site model (CSM).

Data

Numerous studies have documented PCB and other contaminant concentrations in sediment and floodplain soil within the Housatonic River downstream of the GE facility. Most of the floodplain soil where tPCB concentrations exceed 1 milligram per kilogram (mg/kg) is within the approximate extent of the 10-year floodplain between the confluence and Woods Pond. Some areas of floodplain soil with tPCB concentrations greater than 1 mg/kg also exist downstream of Woods Pond Dam. However, these elevated concentrations are detected less frequently downstream of the dam, and concentrations generally decrease with increasing distance from the GE facility.

PCBs have been detected in river sediment in Massachusetts as far downstream as the border with Connecticut, and in Connecticut as far as Derby Dam and beyond into Long Island Sound (other PCB sources have been identified downstream of this dam).

PCBs have also been found in air, surface water, fish, ducks, frogs, squash, corn grown for silage, and wild edible plants grown in floodplain soil. Total PCBs (tPCBs), dioxin-like PCBs, polychlorinated dibenzo-*p*-dioxins (dioxins or PCDDs), and polychlorinated dibenzofurans (furans or PCDFs) were detected at the GE facility, and were COPCs in all media evaluated. Other contaminants, notably pesticides, metals, and polycyclic aromatic hydrocarbons (PAHs) were also detected in sampling programs and evaluated with screening processes to identify additional COPCs.

An overview of the data collected for use in the HHRA is provided in Section 3. More detailed information can be found in Sections 5 through 9 and Appendices A through D.

Identification of COPCs

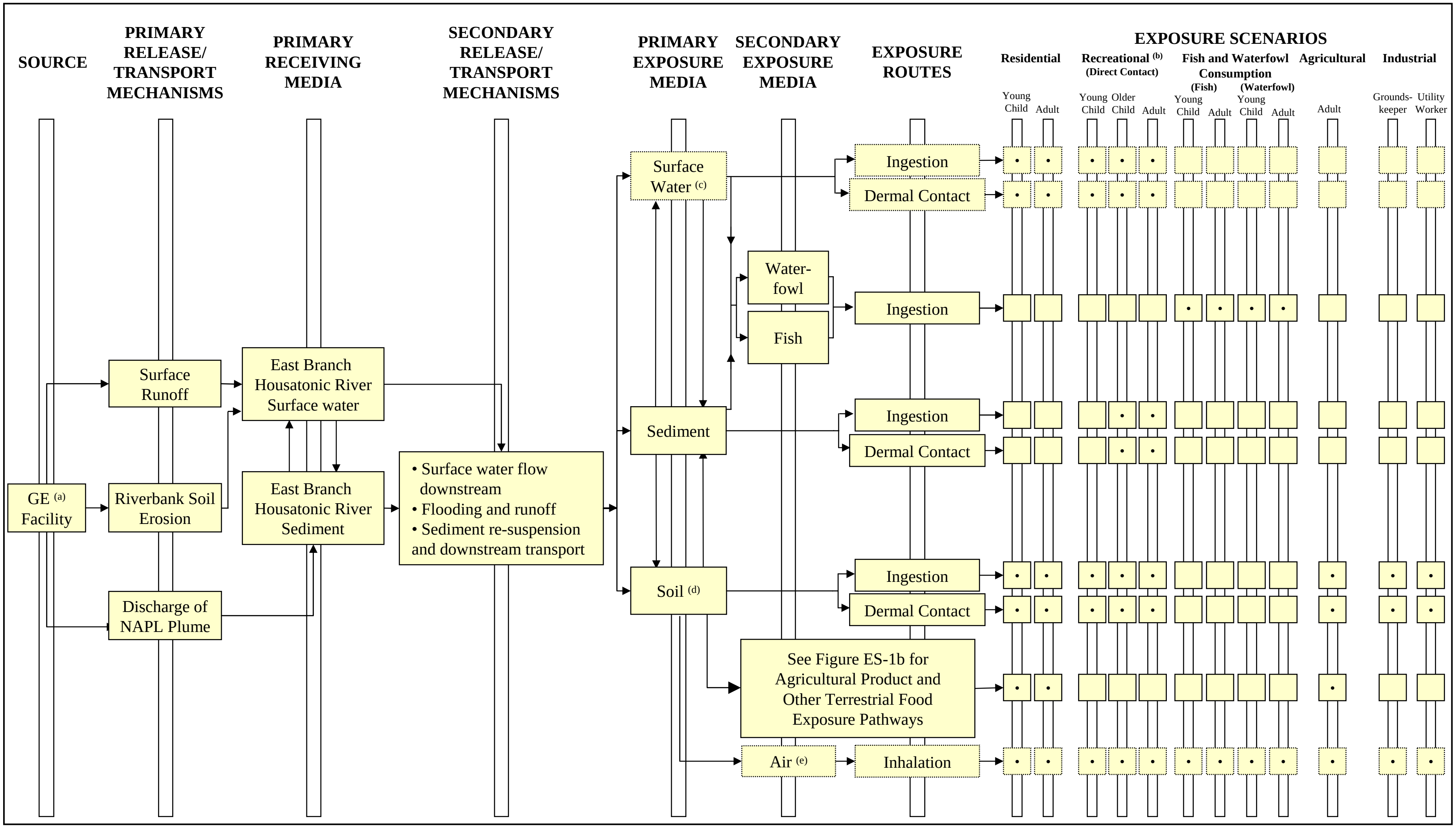
Data that met data quality criteria and were relevant to human health were evaluated to select COPCs for risk analyses for direct contact with soil and sediment, and for consumption of fish, waterfowl, and agricultural products. Because of the known releases from the GE facility and elevated measured concentrations in site media, PCBs were included as COPCs. Dioxins and furans were detected in samples of non-aqueous phase liquid (NAPL) from the GE facility and in sediment samples collected adjacent to the GE facility (BBL and QEA, 2003). Because of their relationship with releases from the GE facility, dioxins and furans were also retained as COPCs.

All other chemicals were eliminated as COPCs for all exposure pathways with the exception of mercury, which was retained in the fish consumption pathway (Reaches 5 and 6 only). Mercury was not a significant contributor to potential risk.

Conceptual Site Model

A conceptual site model (CSM) describes the pathways from the source of contamination through the various environmental media to exposure to individuals categorized by activity and age group. The CSM for the Rest of River is shown in Figure ES-1a. PCBs originating from the GE facility in Pittsfield were initially transported via storm discharges, direct discharges, surface runoff, riverbank and soil erosion, and NAPL plumes to the East Branch of the Housatonic River (primary receiving media). Once in the river, the PCBs partitioned between water and sediment, and were transported downstream and onto the floodplain. These fate and transport processes led to contamination of surface water, sediment, and soil. Human exposure can result from direct contact with these contaminated media (by ingestion or dermal contact) or by inhaling PCBs that volatilize from these media into the air. Human exposure can also result from consumption of aquatic or terrestrial plants or animals that have come into contact with contaminated soil, sediment, and water. Figure ES-1b summarizes the primary consumption pathways for foods contaminated via floodplain soil.

Because of the number of land uses and the variety of primary and secondary exposure media, 26 exposure scenarios were developed. The population considered to have the highest potential exposure to PCBs in the Rest of River is adults and children living in the HRA. This population includes nursing infants exposed by consumption of human milk, and fetuses exposed while in utero. Several subpopulations are considered to have higher exposure to certain contaminated media or locations than the general population; these situations have been identified and evaluated as separate exposure scenarios.



• = Complete exposure pathway

= Incomplete exposure pathway

= Not evaluated quantitatively.

NAPL = nonaqueous phase liquid.

(a) = Includes all facility-related sources such as site soils, Unkamet Brook, Silver Lake, former oxbows, fill areas.

(b) = There are seven variations of the recreational scenario, including general recreation, ATV/dirt and mountain biker, marathon canoeist, recreational canoeist, angler, waterfowl hunter, and sediment exposure. The scenario selected will depend on the medium and exposure area of concern being evaluated.

(c) = Chemical concentrations in surface water were compared to conservative, site-specific screening risk based concentrations (SRBCs) as an initial screening step. Results of the screening process indicated chemical concentrations in surface water below levels of human health concern. Thus, direct contact to surface water was not evaluated quantitatively.

(d) = Includes floodplain and riverbank soil.

(e) = Air sampling conducted at various points along the Lower River resulted in low concentrations of PCBs. An additional sampling and screening level risk assessment was performed. Results of the screening process indicated chemical concentrations in air below levels of human health concern. Thus, inhalation of air was not evaluated quantitatively.

Human Health Risk Assessment
GE/Housatonic River Site
Rest of River

Figure ES-1a

Conceptual Site Model

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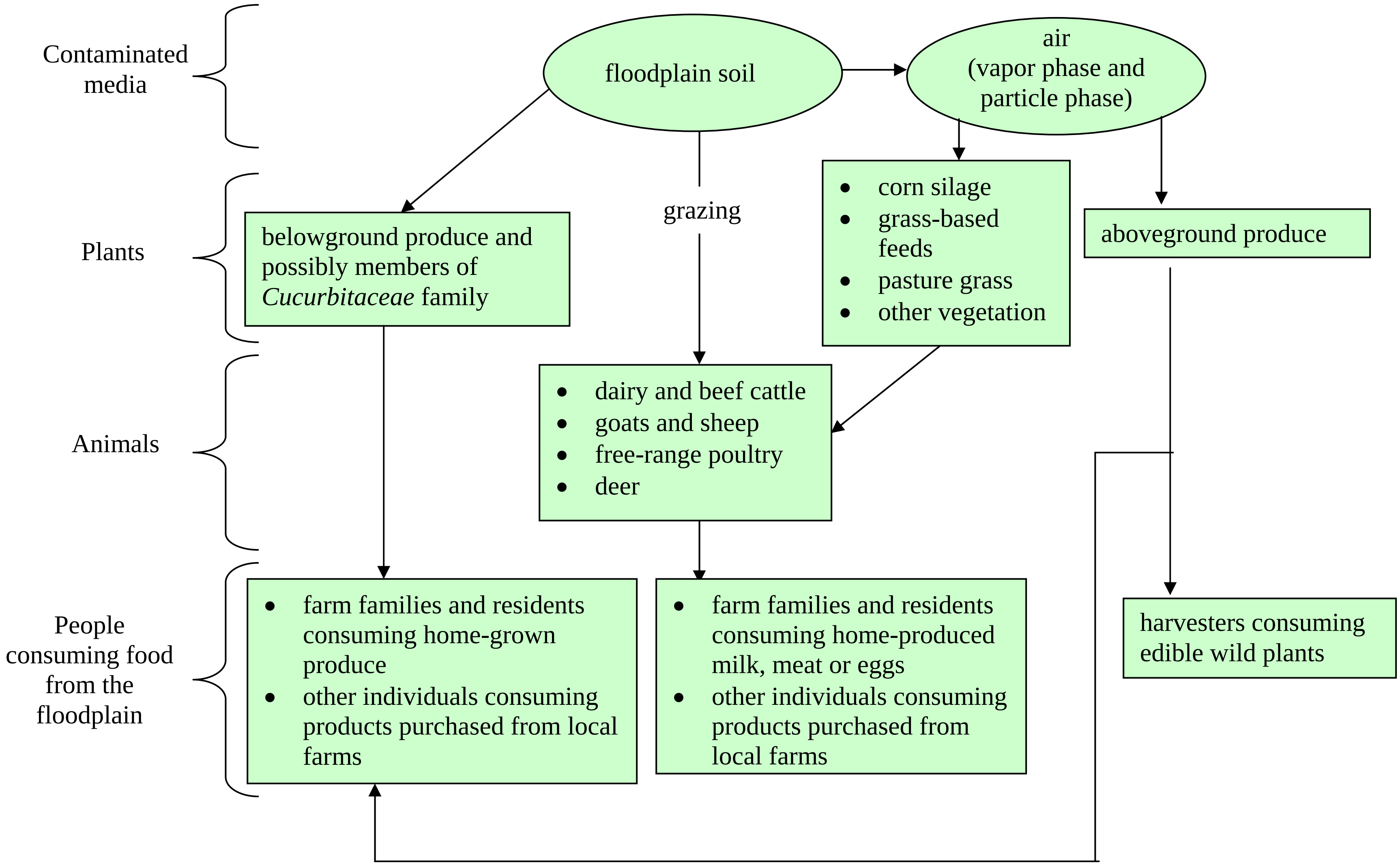

Figure ES-1b Conceptual Model of Agricultural Product and Other Terrestrial Food Exposure Pathways in the Housatonic River Floodplain

The general approach for evaluating the 26 exposure scenarios in a geographical area the size of the HRA was to divide the exposure scenarios into three main categories:

- Direct contact with contaminated media (air, surface water, soil, sediment).
- Consumption of fish, waterfowl, and other aquatic organisms.
- Consumption of agricultural products and other terrestrial foods.

The current and foreseeable future exposure scenarios and exposure areas (EAs) associated with each of these categories were identified. The cancer risks and noncancer hazards associated with these exposures were characterized using both point estimate and probabilistic methodologies.

For direct contact exposures only, screening-level risk assessments were conducted for air, surface water, soil, and sediment. The purpose of the screening-level assessments was to eliminate exposure media or EAs that would not contribute to significant risk based on health-protective screening criteria. The remaining exposure pathways and geographic areas were then characterized more fully with respect to risk.

For the screening level risk assessments, each exposure medium was evaluated separately, and large geographical areas were subdivided into EAs. Exposure concentrations were compared with contaminant- and media-specific benchmark concentrations that are protective of human health. As a result of the screening risk assessments, air and surface water were eliminated as exposure media of concern for all geographic areas. Risks associated with direct contact with floodplain soil were eliminated in Reach 9 and reaches farther downstream, along with many EAs in Reaches 7 and 8, and several EAs in Reaches 5 and 6 (generally those at the edge of the floodplain, or separated from the river by railroad tracks). Risks associated with direct contact with sediment in free-flowing (but not impounded) areas were eliminated in Reaches 7 and 9. Risks associated with direct contact with sediment in free-flowing areas and impoundments in reaches farther downstream were also eliminated. In EAs not eliminated in the screening analysis, risks from direct contact with soil and sediment were evaluated in detail, as described in the Phase 2 Direct Contact with Soil and Sediment section.

TOXICITY ASSESSMENT

The purpose of the toxicity assessment is to present information regarding the adverse effects of the COPCs and to identify and quantify health effects associated with specific doses of COPCs, if possible. The COPCs in this assessment are polychlorinated biphenyls (PCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs or dioxins), and polychlorinated dibenzofurans (PCDFs or furans).

The toxicity assessment describes two toxicity values, cancer slope factors (CSFs), and reference doses (RfDs) used for the quantitative evaluation of potential cancer risks and noncancer health effects. The CSFs and RfDs provide the quantitative relationship between the average daily doses calculated in the exposure assessment and the potential cancer risks and noncancer health effects, respectively, in the risk characterization step. CSFs developed by EPA are plausible upper-bound estimates of carcinogenic potency used to calculate cancer risk from exposure to carcinogens by relating estimates of lifetime average chemical intake to the incremental probability of an individual developing cancer over a lifetime. This means that EPA is reasonably confident that the actual cancer risks are likely to be less than the risks estimated with the upper-bound slope factor. It is not possible to estimate how much less, but risks to some individuals could be zero (EPA, 1986, 1999). The chronic RfD represents an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime (EPA, 1989).

The toxicity assessment also describes the uncertainties associated with the toxicity values, both in the toxicological database and in the methodology for developing toxicity values. In addition, the toxicity assessment presents the toxicological parameters important for relating exposure and dose, such as the extent of absorption of COPCs from soil (from both oral and skin exposures) and food. Finally, the toxicity assessment describes health effects associated with exposures to tPCBs, dioxin-like PCBs, dioxins, and furans, focusing on health effects associated with doses likely under conditions of environmental exposure.

Based on the weight of the scientific evidence, PCBs have been classified as probable human carcinogens (category B2) by EPA. Because PCBs consist of a complex mixture of individual

PCBs (known as congeners) rather than a single chemical, EPA recommends an approach to assess cancer risk that accounts for different PCB mixtures typically found in environmental media. EPA has developed a series of CSFs and criteria for using them to assess risk from PCB mixtures with different properties that affect their toxicity and persistence in the environment, such as the degree of chlorination. The exposure pathways evaluated in this risk assessment all met the criteria for evaluating exposure as a mixture of highly chlorinated PCBs. Thus, the high risk and persistence upper-bound CSF of 2 $(mg/kg\text{-}d)^{-1}$ and the central estimate CSF of 1 $(mg/kg\text{-}d)^{-1}$ were incorporated into the point estimates of reasonable maximum exposure (RME) and the central tendency exposure (CTE) risk estimates, respectively. The upper-bound CSF of 2 $(mg/kg\text{-}d)^{-1}$ was used in the probabilistic risk assessments.

The risks associated with 2,3,7,8-TCDD and other dioxin-like PCDD, PCDF, and PCB congeners were evaluated using a toxic equivalence (TEQ) approach (Van den Berg at al., 1998). Each dioxin-like congener was assigned a toxic equivalency factor (TEF) that is used to transform concentrations of individual dioxin-like PCDD, PCDF, and PCB congeners into equivalent concentrations of 2,3,7,8-TCDD known as TEQ. Toxicity values for 2,3,7,8-TCDD TEQ are not published in EPA's Integrated Risk Information System (IRIS) database. The provisional CSF value of 1.5E+05 $(mg/kg\text{-}d)^{-1}$ was obtained from the *Health Effects Assessment Summary Tables* (HEAST) (EPA, 1997). No noncancer toxicity values are available for PCDD/PCDFs, and noncancer health effects from these compounds were not quantitatively evaluated.

Cancer risks from tPCBs and TEQ are presented separately, and represent two toxicological evaluations of cancer risks from the environmental mixture. The cancer risks from these separate evaluations are not summed, and the potential underestimate of tPCB cancer risk as a result of the potential enrichment of persistent congeners, including dioxin-like PCB congeners, is discussed in the uncertainty analyses of the technical appendices.

Reference doses (RfDs) for two commercial PCB mixtures, Aroclor 1016 and Aroclor 1254, have been published in the EPA IRIS consensus database. The environmental mixture of PCBs at the site most closely resembles the commercial mixture Aroclor 1260, with minor contributions from Aroclor 1254. With respect to chlorine content and environmental persistence, the PCB mixture at this site more closely resembles Aroclor 1254 than Aroclor 1016 (WESTON, 2002; BBL and QEA, 2003). Therefore, the RfD of 0.00002 mg/kg-d (2E-05) based on Aroclor 1254 was used in the assessment of noncancer health effects. The report summarizes potential reproductive, developmental, immunological, and other adverse effects associated with dioxin-like compounds, but no RfD is available to quantify the potential for such noncancer effects.

EXPOSURE ASSESSMENT

The purpose of the exposure assessment is to estimate the nature, extent, and magnitude of potential exposure of adults and children to COPCs. To provide a range of exposure estimates from the point estimate approach, both the reasonable maximum exposure (RME) and central tendency exposure (CTE) scenarios are presented. The RME, an estimate of the upper range of exposure in a population, is based on a combination of the upper and central estimates of exposure parameters representing the 90^{th} percentile or greater of actual expected exposure. The CTE is the central tendency (i.e., average) exposure, which uses average exposure parameters to calculate an average exposure to an individual. Both the RME and CTE analyses are presented for each exposure scenario.

In addition to the point estimate approach, the variability and/or uncertainty of the exposure and resulting risk estimates were quantitatively analyzed using probabilistic approaches. EPA guidance outlines a sequential “tiered” approach to the application of probabilistic models in a risk assessment. Each tier is evaluated and the results are used in conducting the succeeding tiers. In the application of this approach, increasingly complex models and data are used to further quantify the effects of uncertainty regarding risk model input variables on the risk assessment result.

The direct contact and agricultural products risk assessments have two tiers of analysis. The point estimate risk models represent the first tier of the risk assessment. One-dimensional Monte Carlo analyses (MCA) and probability bounds analyses (PBA) comprise the second tier to characterize variability and uncertainty. For fish and waterfowl consumption, a third tier of modeling was conducted in which a microexposure event (MEE) Monte Carlo simulation and a corresponding MEE PBA were conducted. The MEE Monte Carlo simulation is intended to account for the day-to-day and year-to-year variation in an individual's habits (e.g., hunting, fishing, cooking), and for the meal-to-meal and year-to-year variability in the fish and waterfowl that the individual brings home.

Phase 2 Direct Contact with Soil and Sediment

The Phase 2 Direct Contact Risk Assessment evaluated the soil and sediment areas that were retained for further consideration after the screening risk assessment. These land areas were again reviewed and divided into separate EAs based on the following considerations:

- Exposure areas did not extend beyond the boundaries of the site, as defined by the Consent Decree. The site extends to the 1-ppm PCB isopleth, which is approximated by the 10-year floodplain in Reaches 5 and 6, and the 100-year floodplain in Reaches 7 through 9 (the 10-year floodplain has not been mapped for these downstream reaches).
- Individual tax parcels (portion within floodplain) were the starting point for defining individual EAs. These parcels were kept intact, subdivided, or combined with adjacent parcels for evaluation based on the following criteria:
  - Similarity of land use.
  - Similarity of ownership.
  - Number of available soil samples.

Exposure scenarios were evaluated for land uses, and where more than one land use was appropriate, the land use that resulted in the highest exposure and risk was selected for the risk evaluation. The exposure scenarios were grouped into four categories: residential, recreational, agricultural, and commercial/industrial. Both current and reasonably foreseeable future land uses were included. The recreational and commercial/industrial categories were further divided to reflect differences in receptor activities.

The variations of the recreational scenario were:

- General recreation.
- All terrain vehicle (ATV)/dirt and mountain bike riding.
- Marathon canoeist.
- Recreational canoeist/boater.
- Angler.

- Waterfowl hunter.
- Sediment exposure.

The variations of the commercial/industrial scenario were:

- Groundskeeper.
- Utility worker.

There were also two alternatives considered for future residential exposure that differ based on whether the area included an actual or potential lawn area. A single scenario was used to evaluate risks for farmers. All of the scenarios evaluate soil exposures, with the exception of the sediment exposure scenario, which considered sediment exposure from a composite of recreational activities including wading, swimming, fishing, waterfowl hunting, canoeing, and other related activities.

A total of 90 EAs were evaluated for direct contact exposure to soil and 8 EAs were evaluated for direct contact with sediment. In addition, several EAs were divided into subareas based on the observation that distinct activities could occur at specific locations within the EA. In these cases, a risk assessment was conducted for the activity in the subarea in addition to the risk assessment for the EA as a whole.

Exposure point concentrations (EPCs), which are estimates of average soil concentrations to which a receptor would be exposed, were calculated for each EA. EPCs were based on the 95% upper confidence limit (UCL) of the mean of the sampling data in each parcel. Prior to the calculation of the UCL, the sampling data in Reaches 5 and 6 were spatially weighted to account for the non-random pattern of sampling and use-weighted to adjust for differential use of parts of a large parcel.

For each exposure scenario and EA, as appropriate, exposure parameter values for soil ingestion rates, fraction of soil ingested from the site, extent of dermal contact, dermal absorption, body weight, averaging time, and exposure duration were determined for RME and CTE receptors. Similarly, the exposure frequencies (EFs) for the utility worker, waterfowl hunting, fishing, canoeing, dirt bike/mountain bike/ATV, and sediment contact scenarios were used for all EAs for which the scenario was applicable. For future residential scenarios, two alternative EFs were used, with the selection dependent on whether the area included an actual/potential lawn area or less-frequented areas such as inundated wetland and steep banks. Site-specific EFs were developed for general recreation, farming, and landscaper scenarios. In all cases, EFs were determined based on site-specific considerations, including field observations, surveys of the Housatonic River population (MDPH, 1997), and recreational surveys (USFWS, 2001; EOEA, 2000, Statewide Comprehensive Outdoor Recreational Plan [SCORP]). The exposure parameters for each scenario, including the EFs and soil ingestion and dermal intake rates, were developed assuming that all of the exposure to a receptor for that exposure scenario takes place at the EA being evaluated. Thus, it is not appropriate to add risks from different EAs that were evaluated by the same pathway.

In addition to the point estimate risk characterization, the variability and uncertainty associated with each recreational exposure scenario, but not each EA, were characterized using probabilistic methodologies. For the probabilistic assessment, the EPC was assumed to be 1 ppm, and thus, the variability and uncertainty are based on exposure parameters other than the concentration term. Because risks vary proportionately (linearly) with EPC, these results can be scaled up or down to approximate risks for any particular EA or EPC.

Consumption of Fish and Waterfowl

Risks from consumption of fish were evaluated for four different EAs where anglers are known to fish. The EAs are sufficiently large that all angling and harvesting necessary to achieve the consumption rate used in the risk assessment may reasonably take place in a single EA.

Risks from the consumption of waterfowl were evaluated in one EA, the lower portion of the PSA. This area was popular with waterfowl hunters prior to the advisory and supports a resident waterfowl population of sufficient size to accommodate the consumption rates used in the risk assessment. Although no usable waterfowl data were available for areas farther downstream, in the uncertainty section consumption of waterfowl in Connecticut was evaluated using the ratio of sediment tPCB concentrations in Connecticut to those in the PSA to extrapolate a potential contaminant concentration in ducks harvested from Connecticut.

Risks due to consumption of frogs and turtles were addressed qualitatively. Fish consumption advisories are currently in place in both Massachusetts and Connecticut for the Housatonic River due to the PCB contamination. In addition, frog, turtle, and waterfowl consumption advisories are also in place for the Housatonic River in Massachusetts. However, the risks from consumption are evaluated as if no consumption advisories are in place, consistent with EPA policy.

Exposure scenarios for fish and waterfowl consumption were developed for recreational fishing and hunting. There is no evidence of subsistence hunting and angling in the HRA. EPA held discussions with representatives of the Schaghticoke Tribal Nation, which obtained federal acknowledgment (pending appeal) in January 2004. EPA asked the members about the species preferred and consumed from the river. Tribal members responded that they currently practice catch-and-release fishing because of the warnings on fish consumption. In the absence of such warnings, consumption would resume. EPA has evaluated the risks associated with Schaghticoke traditional cooking practices as part of the uncertainty assessment.

Analytical data used to determine the EPCs for fish and waterfowl came from samples that represented species and tissues typically harvested and consumed in the HRA. To the extent possible, site-specific data were used to derive exposure parameters, including exposure duration and frequency of waterfowl meals.

The risks associated with consumption of fish and waterfowl were quantified for PCBs and dioxins, furans, and dioxin-like PCBs, expressed as TEQ. The risks associated with mercury in fish were evaluated for one location where data were available. Other contaminants identified in the chemical analyses were eliminated based on comparisons to risk-based screening concentrations.

Both point estimate and probabilistic methodologies were used to characterize risk to individuals who consume fish and waterfowl. Both methodologies evaluated potential cancer risks and noncancer health effects to children and adults from fish consumption for each of the four separate areas and from consumption of waterfowl from Reaches 5 and 6. In addition, both methodologies used the same site-specific and literature data for exposure parameters and toxicity factors.

Consumption of Agricultural Products

The Agricultural Product Consumption Risk Assessment provides risk estimates for consumption of commercial and backyard agricultural products, specifically, milk, beef, poultry, eggs, and produce. It also includes a qualitative assessment of the risks from other food sources that may be contaminated by tPCBs in floodplain soil, such as deer, goats, and wild edible plants.

Individuals can be exposed to contamination through consumption of animal products. Agricultural products can become contaminated when produced from animals that eat contaminated feed (e.g., corn silage and grass-based feeds) grown in the floodplain, or inadvertently ingest soil while grazing in the floodplain. Home gardens also were considered, although tPCBs and dioxin/furans do not accumulate in plants to the extent that they accumulate in animal products.

In contrast to the direct contact and fish and waterfowl consumption risk characterizations, contaminant concentrations in agricultural products consumed by humans were not measured directly in most cases, but were based on models by which contaminant concentrations in floodplain soil are transferred to plants and animals either directly (soil ingestion, soil-plant transfer) or indirectly (use of corn and hay as animal feed). Model input values were based on site-specific information and information from the literature that is relevant to the site-specific conditions, including the type of PCB mixture in floodplain soil and regional farm management practices.

Because management practices and animal types on any given farm may change over time, a farm-specific assessment would become obsolete when these changes occur. To address this concern, hypothetical scenarios were assessed that reflect the range of current and potential future farm types, management practices (e.g., animal housing and feed) in the floodplain, and PCB concentrations, thus this assessment can be used to assess risk as the practices and/or uses for a given parcel change over time.

Exposure estimates were based on assumed tPCB soil EPCs that reflect the range of concentrations measured in current and potential future agricultural areas and on a range of assumed fractions of agricultural area within the floodplain (i.e., the 1-ppm tPCB isopleth along

Reaches 5 and 6, and the 100-year floodplain along Reaches 7, 8, and 9), with the exception of some residential properties. Also, although tPCB concentrations outside this range have been measured on some recreational properties, no plans to convert these areas to agricultural uses in the future were identified.

Limited PCB and dioxin/furan congener data were available for floodplain soil; therefore, regression models were used to predict congener concentrations from tPCB concentrations.

The predicted food concentrations were combined with site-specific exposure parameters and those derived from EPA guidance documents to estimate doses of PCBs and dioxin/furans. Home-produced food consumption rates were used, which were the most appropriate available data for the farm exposure scenario. These risk estimates can then be applied to evaluate specific agricultural exposures, including parcels with less than 100% of the agricultural lands occurring in the floodplain, and exposures to floodplain soil with average concentrations greater than 2 mg/kg.

RISK CHARACTERIZATION

The purpose of the risk characterization is to integrate the information developed in the exposure assessment and the dose-response (toxicity) assessment into an evaluation of the potential health risks associated with consumption of foods from the floodplain. Cancer risks and noncancer health hazards were evaluated for both the RME and CTE point estimate and the probabilistic assessments.

The EPA cancer risk range identified in the National Contingency Plan (NCP) (EPA, 1990) is approximately 1 in 1,000,000 (expressed as 1E-06, equivalent to 1×10^{-6}), to 1 in 10,000 (expressed as 1E-04, equivalent to 1×10^{-4}) over a 70-year lifetime. Where the cumulative site risk to an individual based on the RME exceeds the 1E-04 lifetime excess cancer risk end of the risk range, action is generally warranted at a site. For sites where the cumulative site risk to an individual based on the RME is less than 1E-04, action generally is not warranted, but may be warranted if a chemical-specific standard that defines acceptable risk is violated or if there are noncancer effects or an adverse environmental impact that warrants action. EPA may also decide that a lower level of risk is unacceptable and that action is warranted where, for example, there are uncertainties in the risk assessment results. Once EPA has decided to take an action, EPA has expressed a preference for cleanups achieving the more protective end of the range (i.e., 1E-06), although strategies achieving reductions in site risks anywhere in the risk range may be deemed acceptable by EPA (EPA, 1991). For noncancer health effects, EPA considers action when the hazard index (HI) exceeds 1.

In addition to the RME and CTE point estimates, probabilistic risk assessments were performed for consumption of fish, waterfowl, and agricultural products, and for direct contact recreational scenarios. The purpose of the probabilistic risk analyses was to comprehensively characterize the statistical distribution of risk by substituting probability distributions for many of the point estimate exposure parameters used as inputs to the point estimate analysis. These probability distributions represent the intrinsic variability and uncertainty associated with the input variables to the risk equation. Monte Carlo simulations or their analogs were used to estimate the probabilistic risk model. In addition, the probabilistic risk assessment included a PBA. These probabilistic evaluations provide estimates of likelihood, or probability, associated with a range of exposures.

The following sections describe the risks for each of the exposure scenarios

Direct Contact Risk

Figure ES-2 presents the range of tPCB RME point estimate cancer risks for each of the receptors for exposure to soil. These ranges of risk represent all of the EAs evaluated using each exposure. For the majority of the EAs/exposure scenario combinations, the tPCB RME cancer risks are within the EPA risk range. For a few EAs with recreational exposures, the tPCB RME cancer risk for an older child is below the EPA risk range but the cancer risk for adult receptors in the same EA is within the risk range. One EA, evaluated for the utility worker, had a risk below the EPA risk range. No EA/exposure scenario combination has an RME tPCB risk above the EPA risk range (1E-04).

Figure ES-3 presents the range of tPCB RME point estimate noncancer HIs for exposure to soil. In contrast to the cancer risk results, HIs for RME receptors exceed the EPA benchmark of 1 for several EAs evaluated with the residential (future), general recreational, and ATV/dirt and mountain biker, and angler scenarios. The young child and older child HIs

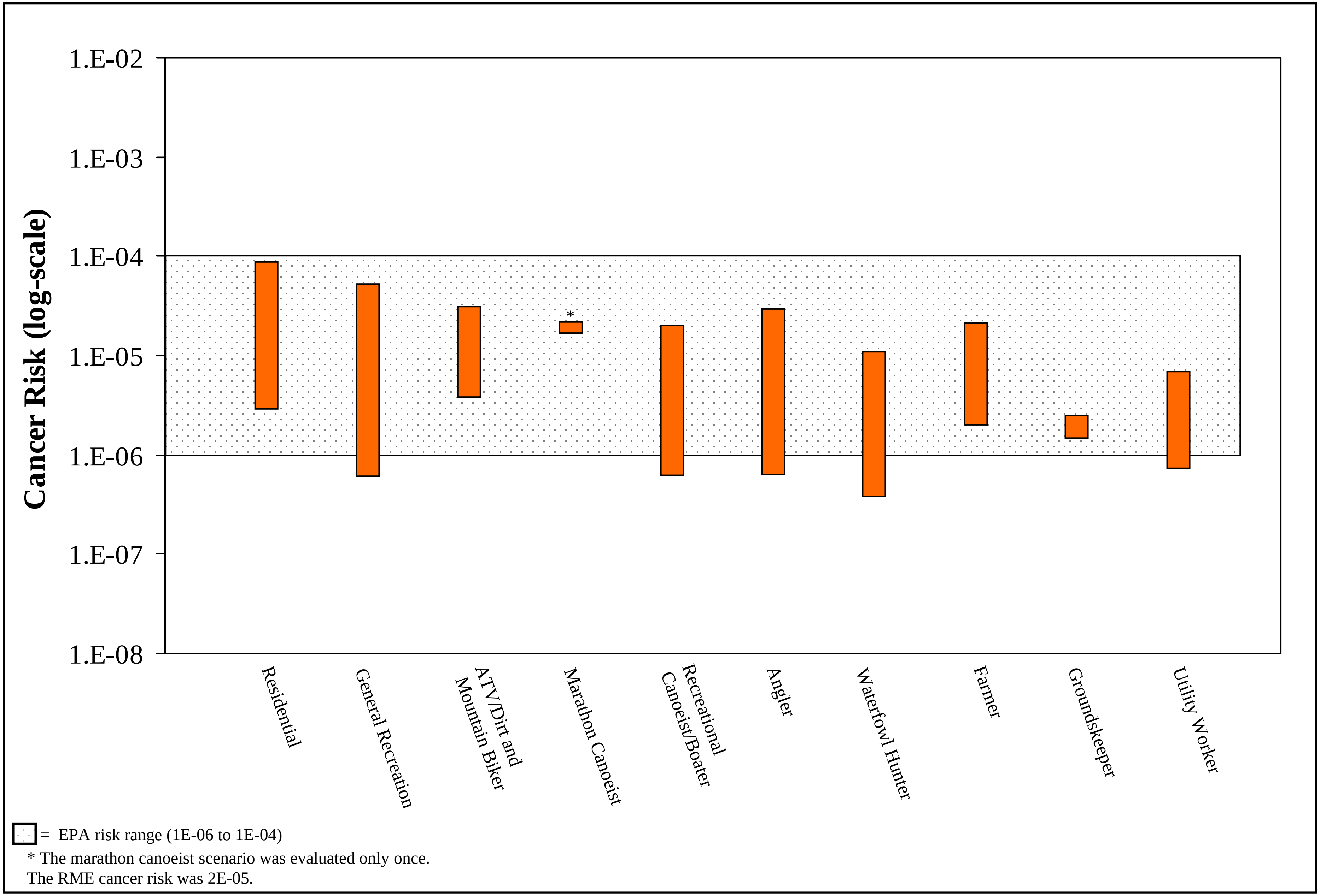

Figure ES-2 Summary of the Range of tPCB RME Cancer Risks from Direct Contact Exposure to Soil

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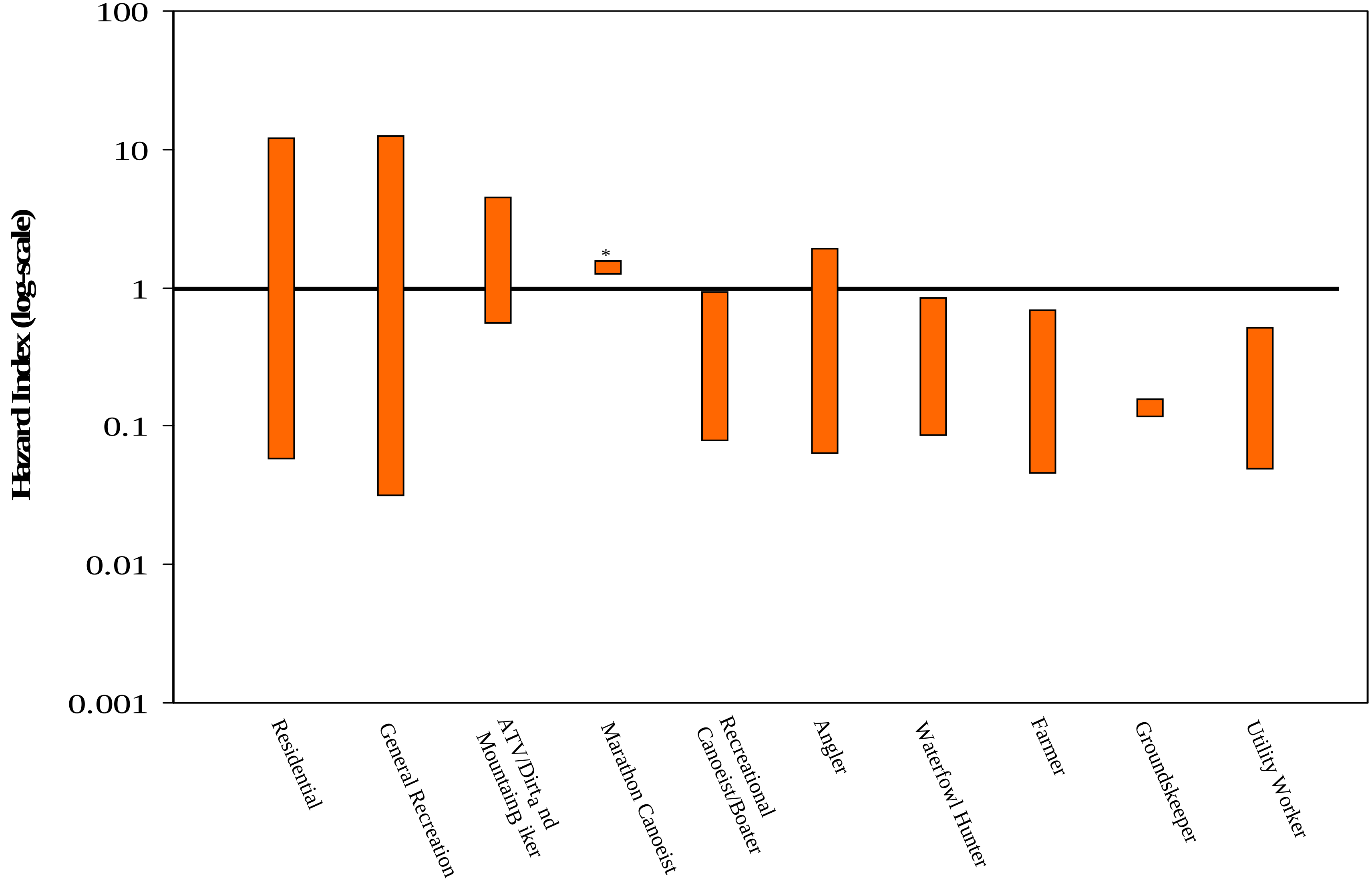

* The marathon canoeist scenario was evaluated only once.
The RME hazard index was 1.4.

Figure ES-3 Summary of the Range of tPCB RME Hazard Indices from Direct Contact Exposure to Soil

exceed the benchmark of 1 more frequently than the adult (for the same EA). For CTE receptors, the HI benchmark of 1 for the young child is exceeded in 5 EAs evaluated with a residential (future) scenario and in one EA evaluated with a general recreational exposure scenario.

Figures ES-4 and ES-5 summarize the point estimate tPCB cancer risk and noncancer HIs for direct contact with sediment for each of the eight sediment EAs. The RME cancer risk is within the EPA range for all of the EAs and the CTE cancer risk is within or below the EPA risk range. The HIs for the RME in sediment EA 3 and EA 7 are above the EPA benchmark of 1. All other HIs (both RME and CTE) are below the EPA benchmark.

Fish and Waterfowl Consumption Risk

Figures ES-6 through ES-9 provide summaries of the tPCB and TEQ cancer risks and tPCB hazard quotients (HQs) calculated using the point estimate, Monte Carlo simulation, and probability bounds approaches, and a comparison of these cancer risks and HQs to the EPA risk range. Using Figure ES-6 as an example, the red diamonds represent the results of the one-dimensional Monte Carlo simulation (light red) and the MEE simulation (dark red). The black horizontal lines (on the red bars) represent the point estimate results for the CTE. For example, the CTE cancer risk from tPCB due to consumption of fish caught in Reaches 5 and 6 is 3E-04 for both the point estimate CTE and the median of the one-dimensional Monte Carlo simulation. The median of the MEE simulation indicates a higher cancer risk. The light and dark bands of red correspond to the uncertainty around the median of the one-dimensional Monte Carlo and MEE simulations, respectively, that was calculated in the PBA.

EPA guidance (EPA, 2001) suggests that risk managers select the RME from the upper (i.e., 90^{th} to 99.9^{th}) percentiles of risk when using a probabilistic assessment. The blue vertical lines represent the RME risk range calculated using the one-dimensional Monte Carlo simulation (light blue) and the MEE simulation (dark blue). The black horizontal lines (on the blue bars)

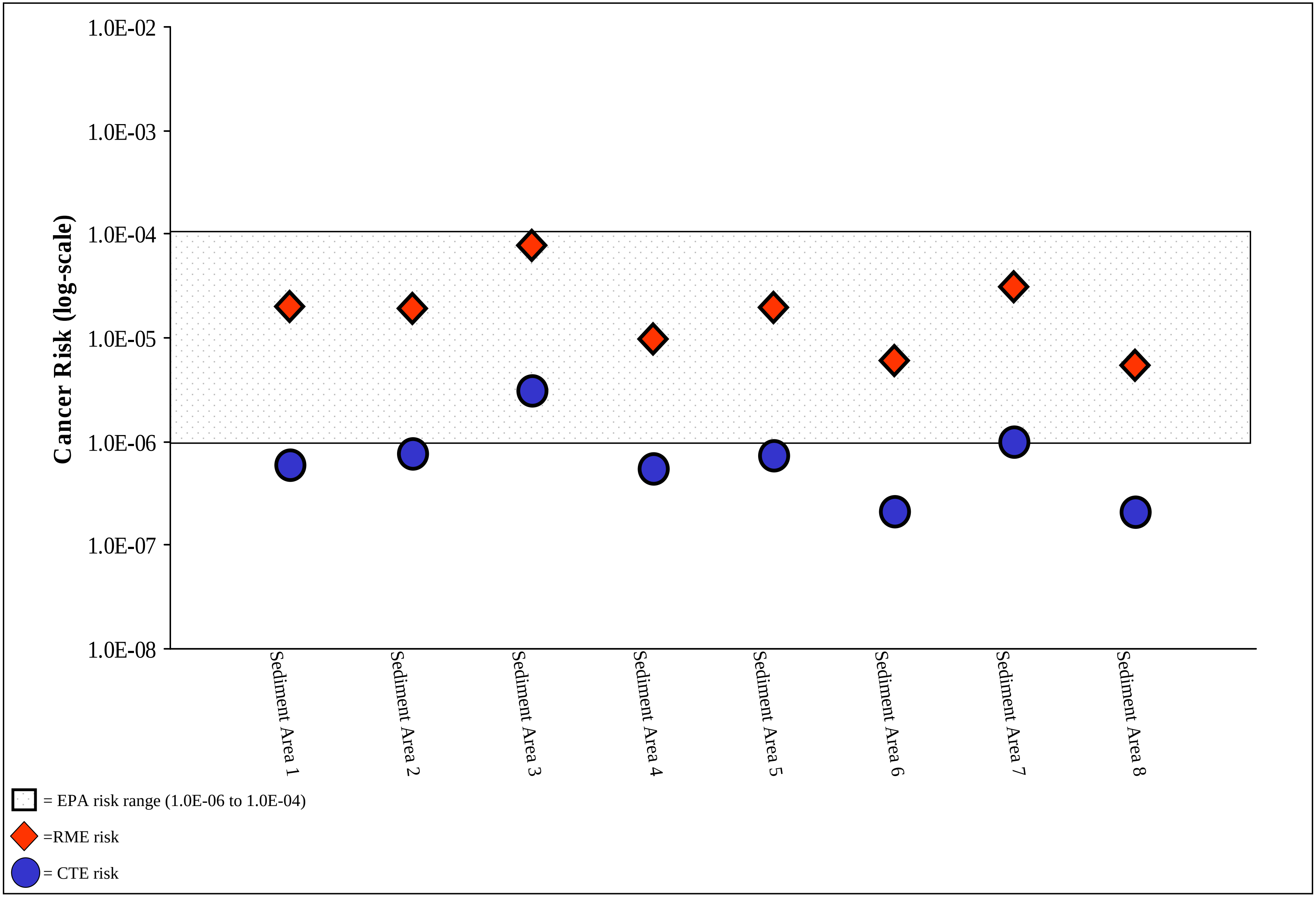

Figure ES-4 Summary of the Range of tPCB Cancer Risks from Direct Contact Exposure to Sediment

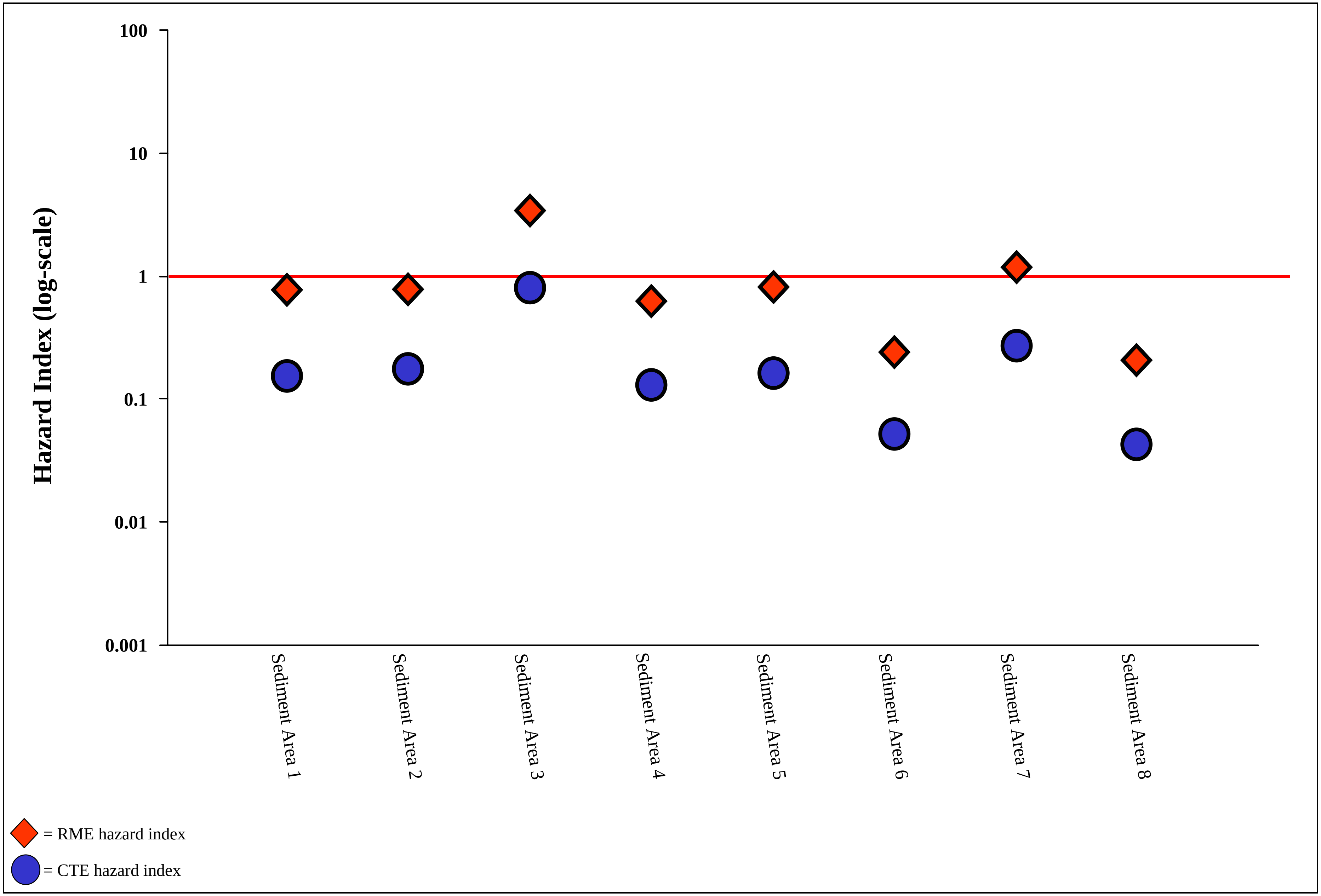

Figure ES-5 Summary of the Range of tPCB Hazard Indices from Direct Contact Exposure to Sediment

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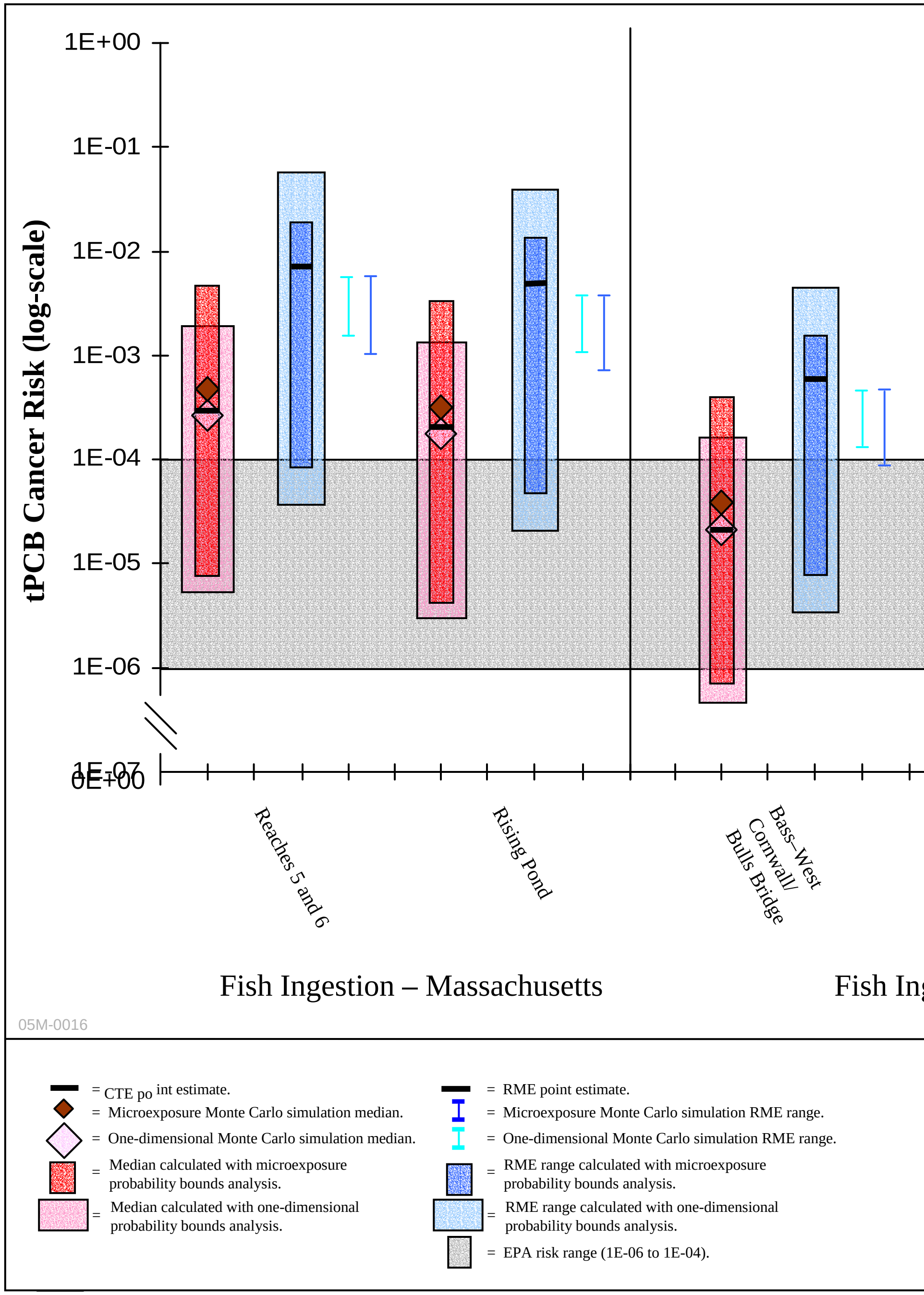

Human Health Risk Assessment
GE/Housatonic River Site
Rest of River

Figure ES-6
Relationship Between Point Estimate, Monte Carlo, and Probability Bounds Analyses for tPCB Cancer Risk from Fish and Waterfowl Consumption

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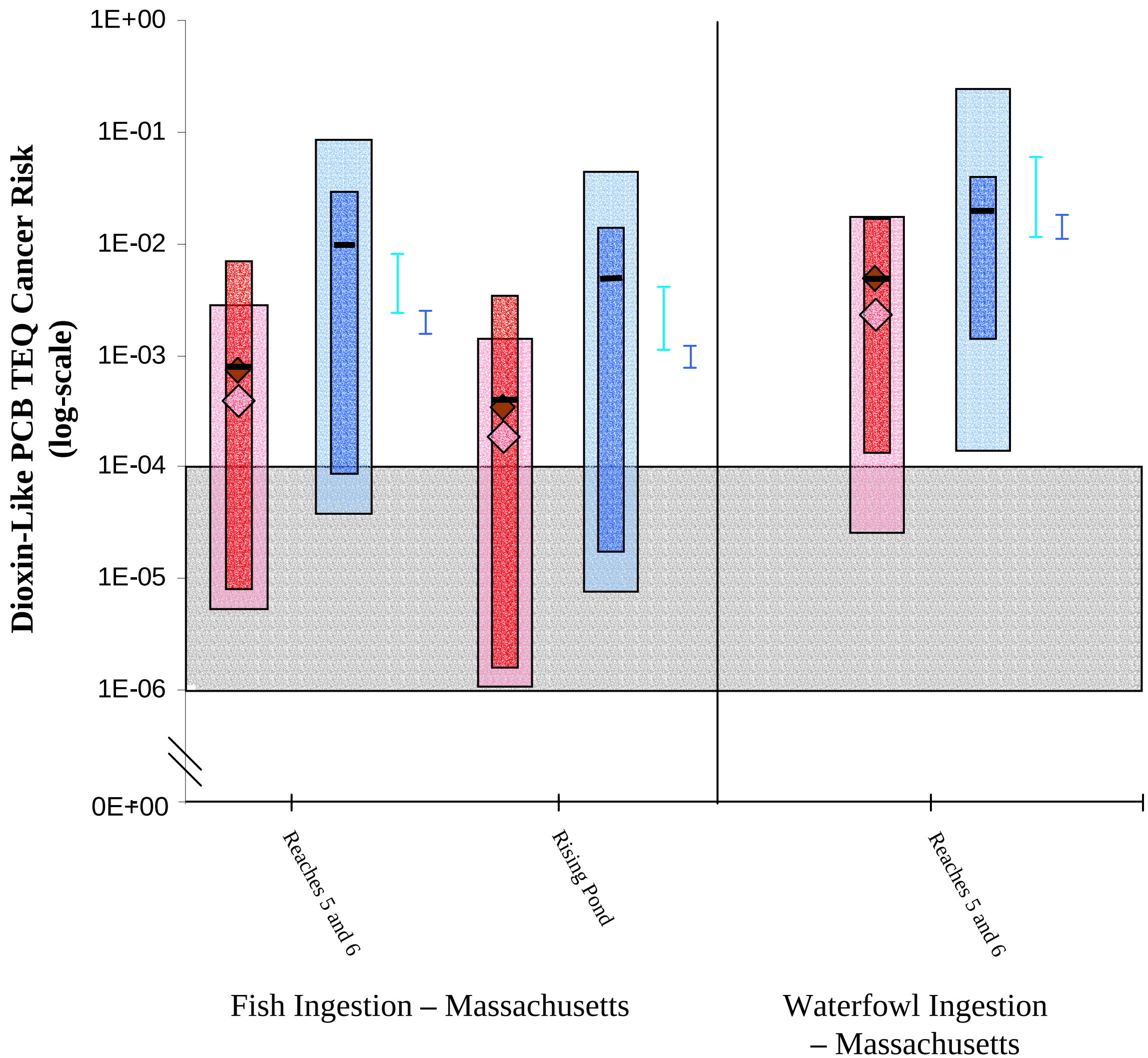
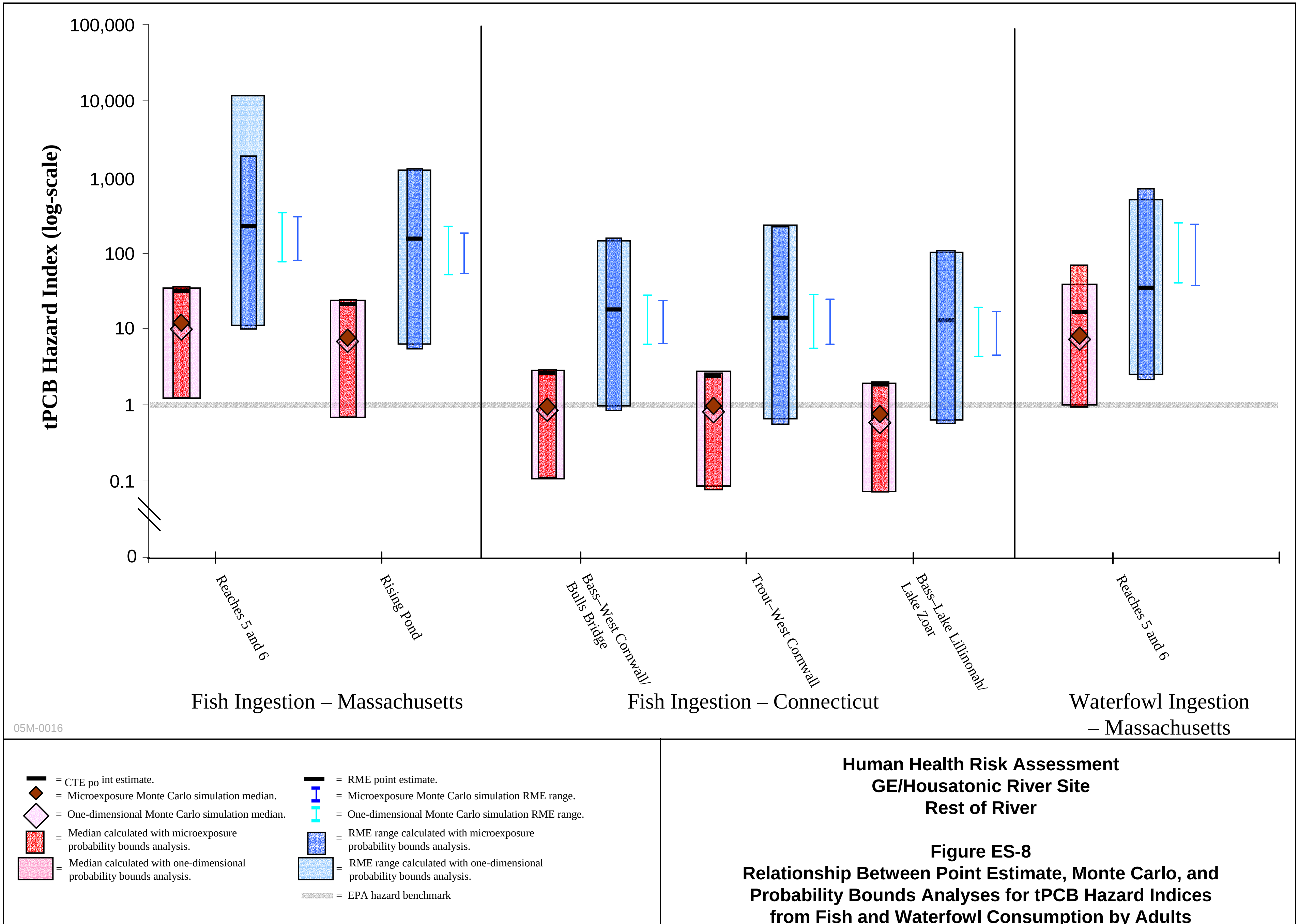


= CTE point estimate.
= Microexposure Monte Carlo simulation median.
= One-dimensional Monte Carlo simulation median.
= Median calculated with microexposure probability bounds analysis.
= Median calculated with one-dimensional probability bounds analysis.
= RME point estimate.
= Microexposure Monte Carlo simulation RME range.
= One-dimensional Monte Carlo simulation RME range.
= RME range calculated with microexposure probability bounds analysis.
= RME range calculated with one-dimensional probability bounds analysis.
= EPA risk range (1E-06 to 1E-04).

Human Health Risk Assessment
GE/Housatonic River Site
Rest of River

Figure ES-7
Relationship between Point Estimate, Monte Carlo, and Probability Bounds Analyses for Dioxin-Like PCB TEQ Cancer Risk from Fish and Waterfowl Consumption



Human Health Risk Assessment
GE/Housatonic River Site
Rest of River

Figure ES-8
Relationship Between Point Estimate, Monte Carlo, and Probability Bounds Analyses for tPCB Hazard Indices from Fish and Waterfowl Consumption by Adults

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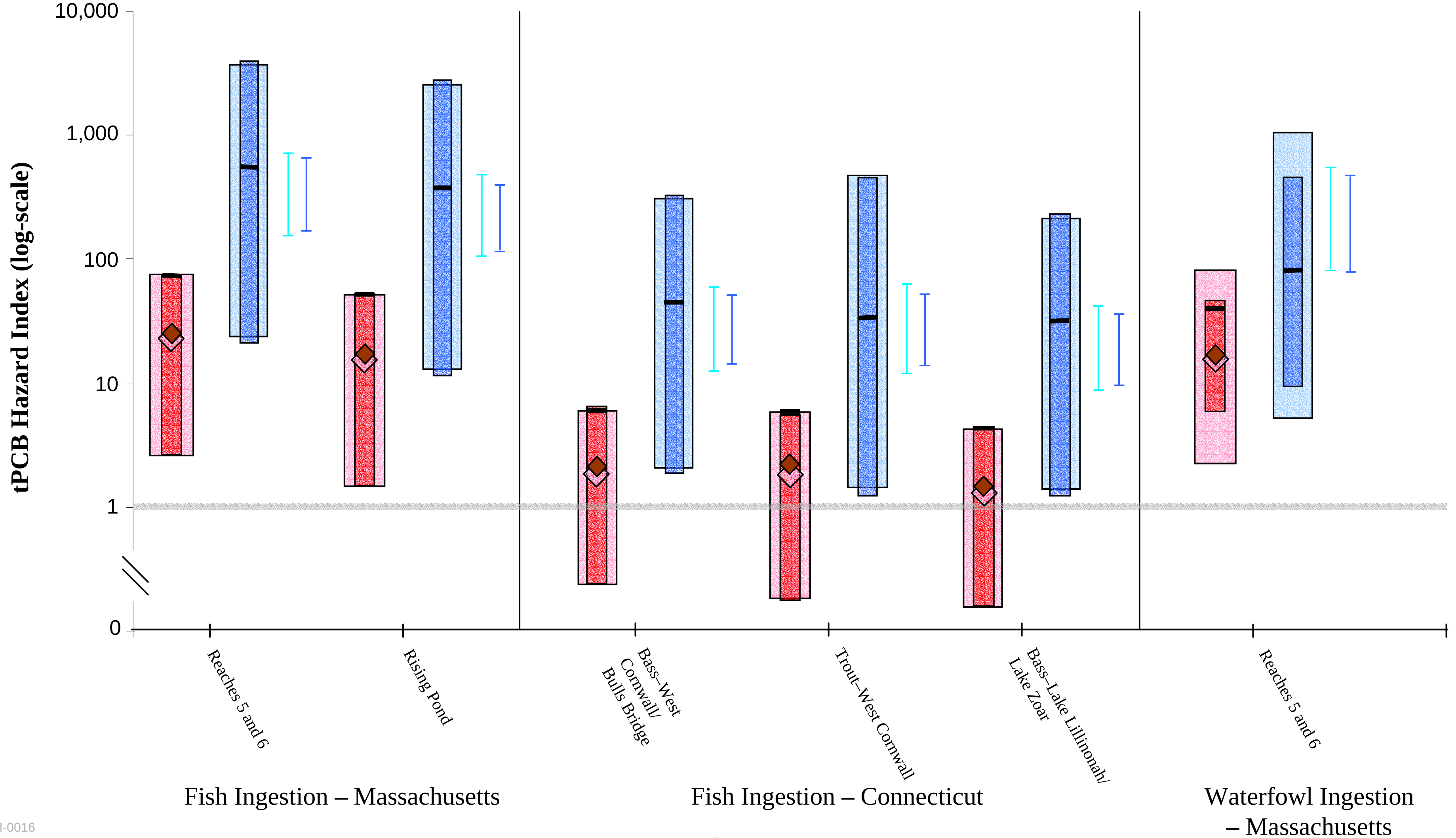

= CTE point estimate.
= Microexposure Monte Carlo simulation median.
= One-dimensional Monte Carlo simulation median.
= Median calculated with microexposure probability bounds analysis.
= Median calculated with one-dimensional probability bounds analysis.
= RME point estimate.
= Microexposure Monte Carlo simulation RME range.
= One-dimensional Monte Carlo simulation RME range.
= RME range calculated with microexposure probability bounds analysis.
= RME range calculated with one-dimensional probability bounds analysis.
= EPA hazard benchmark

Human Health Risk Assessment
GE/Housatonic River Site
Rest of River

Figure ES-9
Relationship Between Point Estimate, Monte Carlo, and Probability Bounds Analyses for tPCB Hazard Indices from Fish and Waterfowl Consumption by Children

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represent the point estimate results for the RME. The light and dark bands of blue correspond to the uncertainty surrounding the high-end percentiles of the one-dimensional and MEE Monte Carlo simulations, respectively, calculated with PBA.

Fish consumption tPCB cancer risks calculated with the point estimate RME and in the high-end range (the 90^{th} to 99^{th} percentile) of both the one-dimensional Monte Carlo and MEE simulations are above the upper end of the EPA risk range for all locations. In Massachusetts reaches, the cancer risks from tPCB high-end risks generally exceed the upper end of the EPA risk range (1E-04), even if all of the uncertainty associated with the data and models were taken into account. However, if all of the uncertainty in the input values or parameterizations that produced the least risk were combined simultaneously and were "true," a combination that has a low probability, the uncertainty associated with the one-dimensional Monte Carlo model indicates that the risks could be between 1E-04 and 1E-05. In the similarly unlikely event that the input values and parameterizations that produced the highest risk were simultaneously correct, the cancer risk could be as high as 6E-02 at the 99^{th} percentile.

A comparison of the tPCB cancer risks calculated with the point estimate CTE and the 50^{th} percentile of the Monte Carlo simulations indicate that the "best estimate" CTE risks for tPCB in Reaches 5 and 6, and Rising Pond are above the EPA risk range, while the "best estimate" CTE risks for tPCB in West Cornwall, Bulls Bridge, and Lakes Lillinonah and Zoar are in the risk range. The PBAs indicate that when all of the uncertainty around the median is included, the tPCB cancer risks in the Massachusetts reaches may be substantially above (between 1E-03 and 1E-02) to within the EPA risk range (between 1E-05 and 1E-06). The uncertainty bounds associated with the CTE risks in West Cornwall and the lower reaches straddle the risk range.

The final two bars in Figure ES-6 summarize the range of tPCB cancer risks due to waterfowl ingestion. As with fish ingestion, the high-end tPCB cancer risk estimates are above the EPA risk range in the point estimate and both Monte Carlo simulations. The uncertainty around the high-end range for the one-dimensional Monte Carlo simulation ranges from a high of 2E-02 at the 99^{th} percentile to a low of 1E-05 for the 90^{th} percentile. In the MEE model, even the low end of the uncertainty at the 90^{th} percentile is 1E-04, the upper bound of the EPA risk range. The CTE tPCB cancer risk based on the CTE and Monte Carlo simulations is 1E-04 or higher.

Accounting for all of the uncertainty, the results indicate that the CTE risk could be greater than 1E-03 or less than 1E-05.

Figure ES-7 includes the dioxin-like PCB TEQ results from fish consumption at the two locations in Massachusetts where congener data were available and from waterfowl consumption in Reaches 5 and 6. The dioxin-like PCB TEQ cancer risks based on the fish consumption point estimate RME and the 90^{th} to 99^{th} percentiles of both Monte Carlo simulations are above the upper end of the EPA risk range. If all of the uncertainty in the input values or parameterizations that produced the least risk were combined simultaneously and were "true," a combination that has a low probability, the uncertainty associated with the one-dimensional Monte Carlo model indicates that the risks could be between 1E-04 and 1E-05. In the similarly unlikely event that the input values and parameterizations that produced the highest risk were simultaneously correct, the cancer risk could be as high as 3E-02 at the 99^{th} percentile. A comparison of the tPCB cancer risks calculated with the point estimate CTE and the 50^{th} percentile of the Monte Carlo simulations indicates that the CTE risks for tPCB in Reaches 5 and 6 and Rising Pond are above the EPA risk range, while the CTE risks for tPCB in West Cornwall, Bulls Bridge, and Lakes Lillinonah and Zoar are within the EPA risk range. The PBAs indicate that when the lower bound of the uncertainty around the median is considered, the tPCB cancer risks in the Massachusetts reaches may be within the EPA risk range, and there is some possibility that the CTE risks in West Cornwall and the lower reaches are below the risk range.

The dioxin-like PCB TEQ cancer risks calculated with the point estimate CTE and the 50^{th} percentile of the Monte Carlo simulations indicate that the CTE risks are also greater than the upper end of the EPA risk range. The PBAs indicate that when all of the uncertainty in input values, parameterizations, and models around the median is included, the TEQ cancer risk estimate could be as high as 7E-03 to as low as 5E-06 for Reaches 5 and 6.

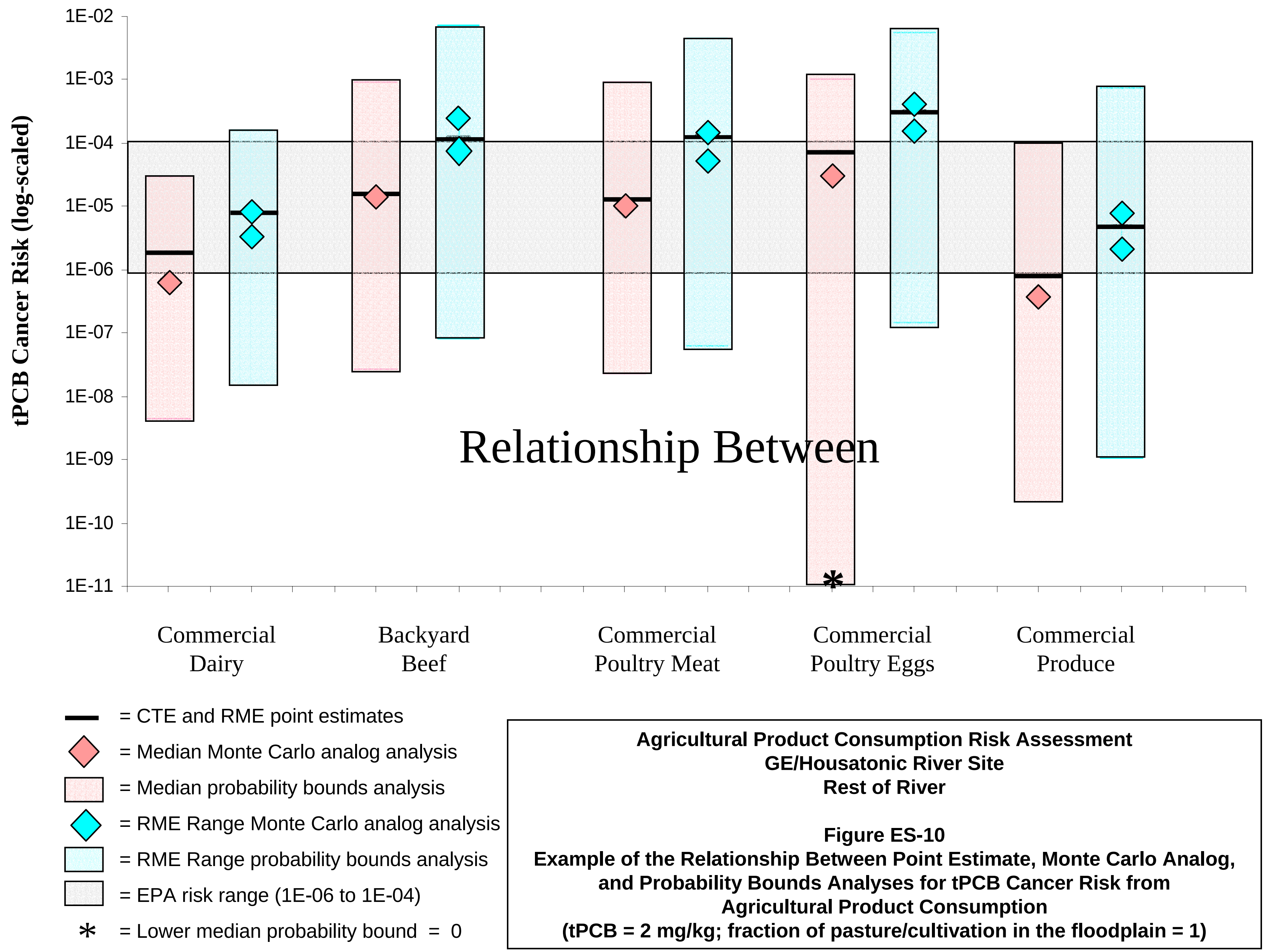
The final two bars in Figure ES-7 summarize the range of dioxin-like PCB TEQ cancer risks due to waterfowl ingestion. As with fish ingestion, the high-end TEQ cancer risk estimates are above the EPA risk range in the point estimate and both Monte Carlo simulations. The CTE risk estimates are also above the upper end of the cancer risk range; however, the uncertainty around the CTE risks for the one-dimensional Monte Carlo simulation ranges from within to above the EPA cancer risk range.

Figures ES-8 and ES-9 include the results for adults and children, respectively, from fish consumption at the four locations, with bass and trout evaluated separately at West Cornwall, and from waterfowl consumption in Reaches 5 and 6. The tPCB HIs based on the both the adult and child fish consumption point estimate and Monte Carlo simulations for high-end receptors are above the EPA benchmark of 1 for all locations. For example, the point estimate HIs for RME children and adults in Reaches 5 and 6 were 550 and 230, respectively. For children at all locations, the uncertainty analyses for both Monte Carlo simulations indicate that the EPA benchmark is exceeded even at the 90th percentile of the distribution and in the unlikely event that the input values and parameterizations that produced the lowest risk were simultaneously correct. In the Massachusetts reaches, HIs for CTE child receptors (50th percentile of the Monte Carlo distributions) exceed the benchmark of 1, even when all the uncertainty is considered. In Connecticut reaches, Monte Carlo simulations indicate that the adult CTE receptors have HIs near 1 while the child CTE receptors have HIs of 1 to 3, above the EPA risk range. Including the uncertainty in all of the input values, parameterizations, and models, the HI for CTE receptors in Connecticut may be above or below the EPA benchmark of 1.

The final two bars in Figures ES-8 and ES-9 summarize the noncancer hazards due to waterfowl ingestion. Both the high-end and CTE HIs for children and adults are above the EPA benchmark of 1, even if all of the uncertainty in the input values or parameterizations that produced the least risk were combined simultaneously. The point estimate HIs for RME children and adults are 81 and 35, respectively.

Agricultural Product Consumption Risk

Figures ES-10 through ES-12 provide summaries of the tPCB cancer risks and tPCB HIs calculated using the point estimate, MCA analog, and probability bounds approaches, and a comparison of these cancer risks and HIs to the EPA risk range. The results in these figures are based on an assumed tPCB floodplain soil EPC of 2 mg/kg with all agricultural



Agricultural Product Consumption Risk Assessment
GE/Housatonic River Site
Rest of River

Figure ES-10
Example of the Relationship Between Point Estimate, Monte Carlo Analog, and Probability Bounds Analyses for tPCB Cancer Risk from Agricultural Product Consumption
(tPCB = 2 mg/kg; fraction of pasture/cultivation in the floodplain = 1)

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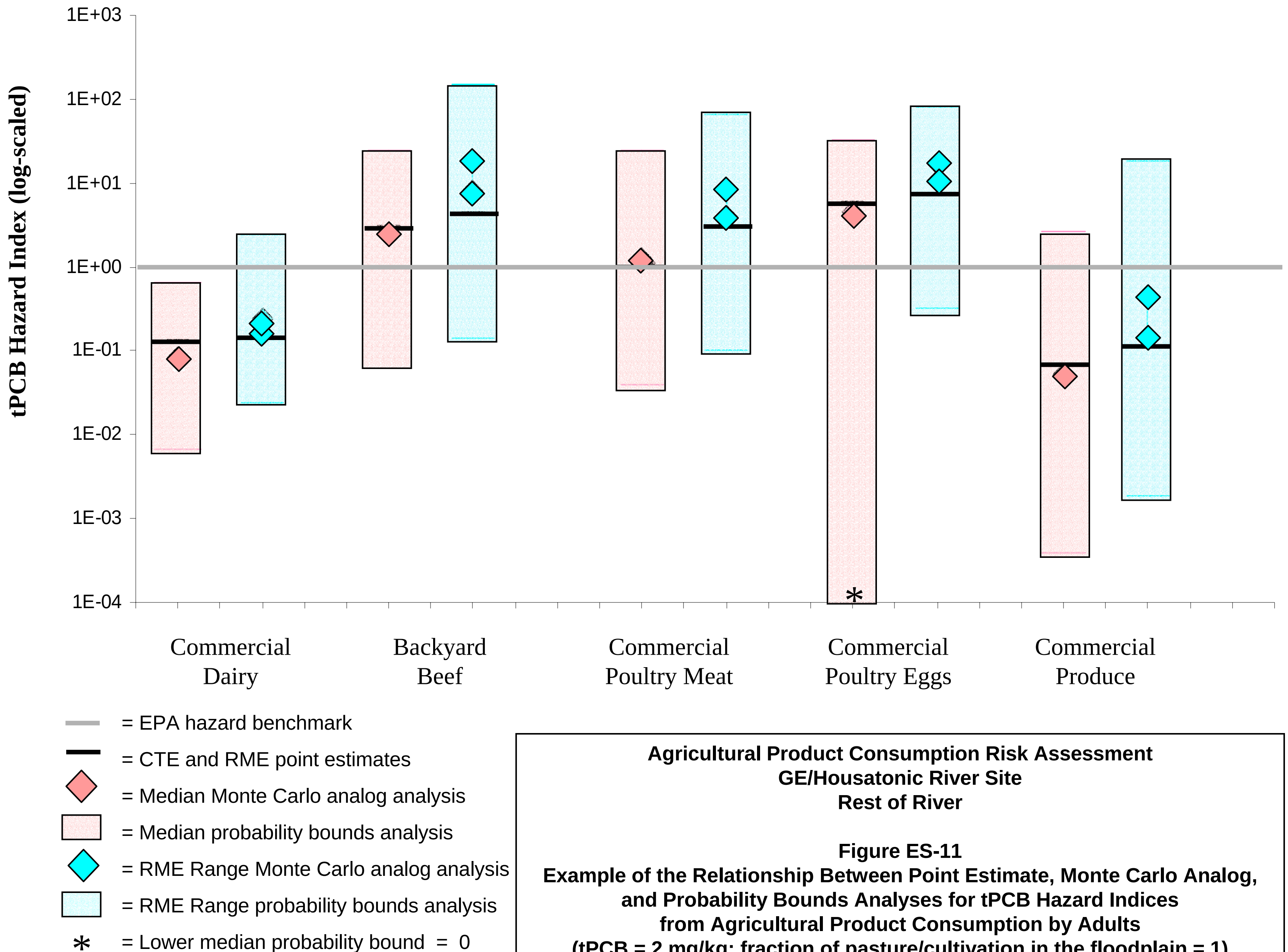
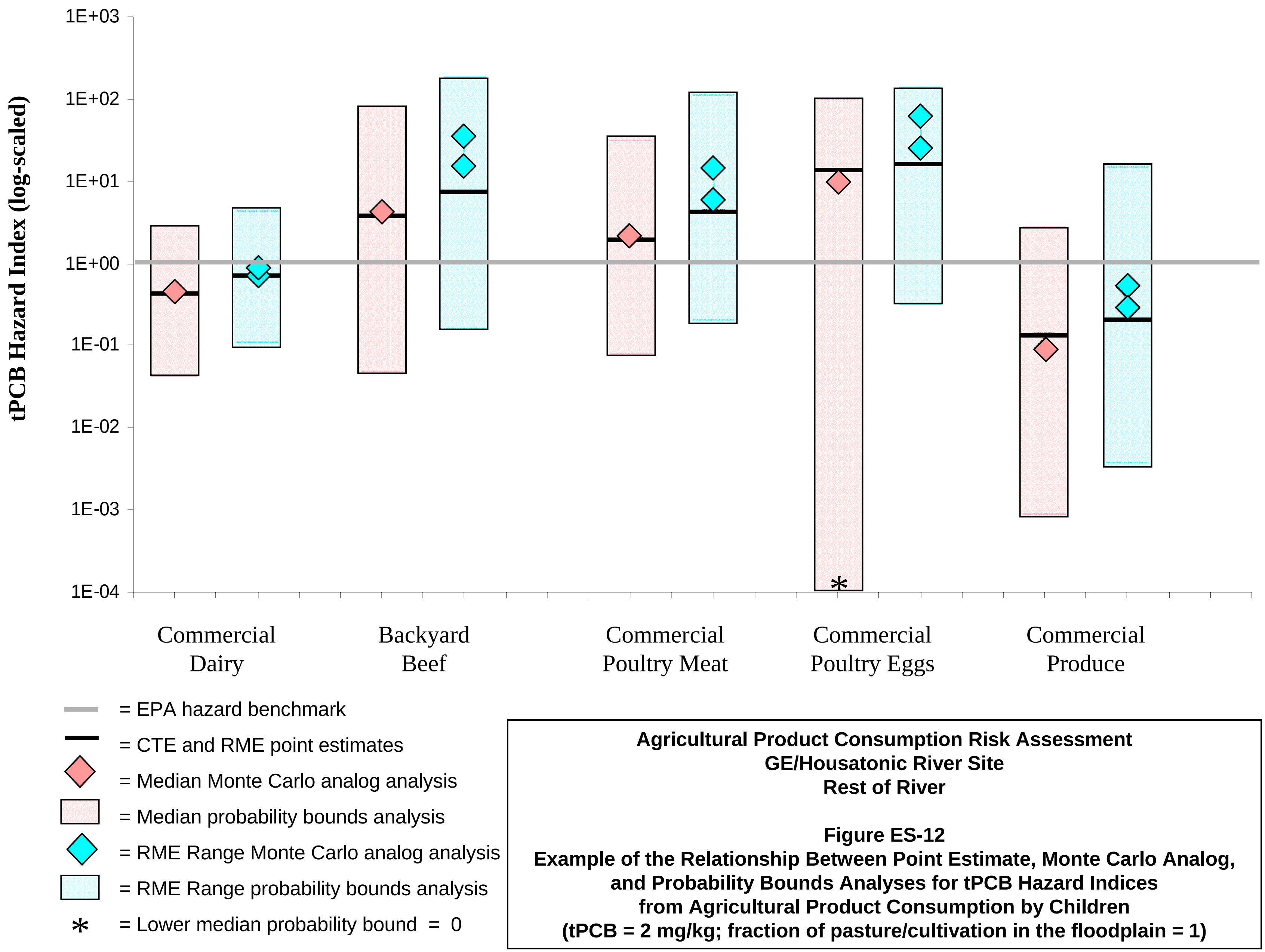


Agricultural Product Consumption Risk Assessment
GE/Housatonic River Site
Rest of River

Figure ES-11
Example of the Relationship Between Point Estimate, Monte Carlo Analog, and Probability Bounds Analyses for tPCB Hazard Indices from Agricultural Product Consumption by Adults
(tPCB = 2 mg/kg; fraction of pasture/cultivation in the floodplain = 1)



Agricultural Product Consumption Risk Assessment
GE/Housatonic River Site
Rest of River

Figure ES-12
Example of the Relationship Between Point Estimate, Monte Carlo Analog, and Probability Bounds Analyses for tPCB Hazard Indices from Agricultural Product Consumption by Children
(tPCB = 2 mg/kg; fraction of pasture/cultivation in the floodplain = 1)

activities occurring within the floodplain (i.e., fraction = 1). As with the fish and waterfowl figures, the red bars summarize the results for the CTEs and the blue bars summarize the results for the high-end exposures associated with each agricultural scenario. EPA guidelines for cancer risks and noncancer health effects are noted by a gray shaded area and a gray line, respectively.

Figure ES-10 presents the tPCB cancer risk results for the five agricultural pathways currently operating in the floodplain. Risks are shown assuming that the tPCB floodplain soil EPC is 2 mg/kg and all agricultural operations occur in the floodplain. However, other combinations of EPC and fraction in the floodplain could result in different risks.

Commercial poultry egg consumption tPCB cancer risks calculated with the point estimate RME and the 95^{th} percentile of the MCA analog are above the upper end of the EPA risk range. The RME point estimate and MCA analog results for the backyard beef and commercial poultry meat scenarios span the upper end of EPA's risk range (i.e., the 99^{th} percentile of the MCA analog is above the upper end of the EPA risk range, but the 90^{th} percentile of the MCA analog is within EPA's risk range). Point estimate and MCA analog results for other agricultural exposure scenarios are within or, in the case of commercial produce, below EPA's risk range. However, the uncertainty around the median and RME range of the MCA analog generally spans the entire EPA risk range.

Figures ES-11 and ES-12 present the tPCB HI results for an adult and child respectively, for the five agricultural pathways currently operating in the floodplain. Risks are calculated assuming that the tPCB floodplain soil EPC is 2 mg/kg and all agricultural operations occur in the floodplain.

The tPCB HIs based on both the adult and child backyard beef, commercial poultry meat, and commercial poultry egg consumption point estimate and MCA analog for high-end and CTE are above the EPA benchmark of 1. The commercial dairy and commercial produce point estimate and Monte Carlo analog HIs are below the benchmark for both CTE and high-end exposure. However, when uncertainty is taken into account, the upper-bound HIs are above the risk range, with the exception of the median probability bounds for the adult commercial dairy scenario.

Cumulative Risks

Because of the size of the area under evaluation, the large number of potential exposure pathways, and the wide variety of potential combinations of exposure possible at this site, the major exposure pathways were evaluated separately. However, any particular individual could be exposed to COPCs from more than one of these pathways. According to EPA risk assessment guidance (EPA, 1989), a risk assessment should identify and combine exposure pathways to which the same individual may be consistently exposed. This combined exposure is known as cumulative risk.

The determination of which exposure scenarios are appropriate to combine requires review of the exposed populations evaluated in each exposure scenario, and identification of activity patterns that an individual within these populations may have. It is appropriate to combine exposure scenarios that involve the same subpopulation of individuals, such as direct contact with soil and sediment and fish consumption for anglers. It is also reasonable to combine risks from different exposed populations if there is information that individuals may be members of two populations, such as hunters and anglers. Section 10.1 of this volume provides guidance and tools for combining risks from multiple exposure scenarios and EAs. A comparison of the magnitudes of the cancer risks and noncancer hazards associated with selected pathways indicates the following:

- Risks from consumption of fish throughout the Rest of River, from the confluence in Pittsfield in Massachusetts to Lake Zoar in Connecticut, are above the EPA risk range and dominate the total risk when combined with any direct contact exposure to soil and sediment.
- Risks from consumption of waterfowl are above the EPA risk range and dominate the total risk when combined with any direct contact exposure to soil and sediment.
- Risks from consumption of fish and waterfowl in the vicinity of Woods Pond are comparable, and both food sources contribute significant risk for individuals who both hunt and fish.
- Risks from backyard gardens with tPCB soil concentrations of 2 mg/kg do not result in elevated risks either alone or combined with residential exposure.

- Risks from backyard beef, dairy, and/or poultry operations with tPCB soil concentrations of 2 mg/kg are above the EPA risk range. These risks dominate the total risk when combined with a direct contact residential exposure.

Potential Exposures to Nursing Infants

The evaluations described in the above sections were based on exposures to tPCBs and TEQ by adults and children living in the HRA. However, PCBs, dioxins, and furans accumulate in lipid-rich tissue, including breast milk, and exposures to females prior to or during nursing may result in an increase in PCB and TEQ concentrations in breast milk. This, in turn, would result in elevated exposures to a nursing infant. A perspective on the breast milk exposure pathway is presented in Section 10.3 by comparing predicted site-related breast milk contaminant concentrations with those measured in the general population. The analysis indicates that both high-end and CTE patterns of fish consumption from the PSA and high-end pattern of waterfowl consumption will result in elevated concentrations of tPCBs. No elevation in breast milk concentrations of PCBs is anticipated as a result of direct contact exposure to soil and sediment.

UNCERTAINTY ANALYSIS

EPA policy and guidance (EPA, 1995) recommend that a thorough discussion of the variability and uncertainty surrounding the calculation of risk be provided to inform decisionmakers when considering risk management alternatives. This risk assessment used multiple approaches to characterize the variability and uncertainty:

- Point estimate calculations of both reasonable maximum exposure (RME) and central tendency exposure (CTE).
- Monte Carlo simulations to characterize variability in risks, providing estimates of both a CTE and an RME range (i.e., 90^{th} to 99.9^{th} percentiles).
- Probability bounds analysis (PBA) to quantify uncertainty in the risk assessment modeling assumptions, including the derivation of point estimates and probability distributions.
- Sensitivity analyses to identify the contribution of individual exposure parameters to variability and uncertainty.

- Qualitative discussion describing sources of uncertainty in the underlying data, the selection of parameter values, and modeling assumptions.
- Bounding analyses based on the point estimate approach to characterize higher risk behaviors for consumption of fish that are not occurring at this time.

Each of the exposure pathways is discussed separately in Sections 7 through 9, and pathway-specific uncertainty analyses are included in these sections. In addition, a discussion of the uncertainty associated with the toxicity assessment is provided in Section 4.

MAJOR FINDINGS

This report evaluated the risks to adults and children resulting from exposure to PCBs and dioxin-like congeners (including PCBs, furans, and dioxins) that are currently located in the riverbank and floodplain soil, sediment, and biota at the GE/Housatonic River Site, Rest of River. Multiple exposure pathways and the resultant cancer risks and noncancer hazards were evaluated individually, including the following:

- Direct contact with soil.
- Direct contact with sediment.
- Consumption of fish.
- Consumption of waterfowl.
- Consumption of dairy, beef, egg, or poultry products from commercial farms.
- Consumption of dairy, beef, egg, or poultry products from backyard farms.
- Consumption of produce from backyard gardens and commercial farms.
- Consumption of wild edible plants.

Most of these exposure pathways were evaluated at multiple locations in the Housatonic River and its floodplain.

The major findings of the Phase 2 Direct Contact Risk Assessment include:

- Point estimate RME cancer risks from soil exposure to tPCBs are within the EPA risk range. All CTE risks for exposure to tPCBs were within or below the EPA risk range, typically less than 1E-05.
- Noncancer hazard indices (HIs) from soil exposure to tPCBs exceeded 1 in some EAs for about half of the RME scenarios. For most of these exceedances, the HIs were below 10. Only two of the scenarios had CTE HIs that exceeded 1.

- Cancer risks from sediment exposure to tPCBs were within the EPA risk range at all eight sediment EAs.
- Noncancer HIs for the RME exceeded 2 at four of the eight sediment EAs. None of the HIs exceeded 10.
- Noncancer risks for both soil and sediment included only an evaluation of tPCBs. Because no reference dose (RfD) is available for TEQ, this potential hazard could not be quantified.
- The regression analysis performed for tPCBs and soil exposure to TEQ resulted in an increase in cancer risk for all scenarios, but the risks still did not exceed the risk range.

The major findings of the Fish and Waterfowl Consumption Risk Assessment include:

- For the fish and waterfowl consumption scenarios, the cancer risks from tPCBs exceed EPA's risk range in all of the EAs. The cancer risks from TEQ exceed EPA's risk range in all EAs for which TEQ is evaluated.
- Cancer risks from tPCB and TEQ for high end (RME) receptors are similar (within a factor of two) to each other for the fish consumption scenarios in which both COPCs were evaluated (PSA [Reaches 5 and 6] and Rising Pond [Reach 8]).
- Cancer risk from TEQ exceeds risk from tPCBs for the waterfowl consumption scenario.
- For the fish consumption scenarios, the noncancer hazard benchmark for adults and children was exceeded at all locations, by factors between 22 and 550 in Massachusetts, and by factors between 2 and 43 in Connecticut.
- For the waterfowl consumption scenarios, the noncancer hazard benchmark for adults and children was exceeded by factors between 7 and 80.
- Consumption of fish and waterfowl from the vicinity of Woods Pond contributes significant risk for individuals who both hunt and fish.
- A sensitivity analysis shows that the consumption rates for fish and waterfowl have a greater influence on the risk than any other exposure variable. The consumption rates used in this risk assessment are considered reasonable and conservative estimates of future activity.

The major findings of the Agricultural Product Consumption Risk Assessment include:

- Risk estimates associated with backyard farms exceeded risk estimates associated with commercial farms. This occurred because backyard animals were assumed to have greater access to floodplain soil and to be fed higher proportions of grass-based feed. Grass-based feed was the most important exposure medium for dairy and beef cattle, and soil was the most important exposure medium for poultry.

- Total PCB cancer risk estimates and noncancer HIs associated with home garden produce consumption were less than those associated with animal product consumption, reflecting the lower rate of PCB accumulation in plants relative to animal products.

- All TEQ cancer risk estimates were dominated by PCB-126 because the CSF for TEQ is greater than the CSF for tPCBs, and PCB-126 is the most dioxin-like of the PCB congeners and is assumed to bioaccumulate in animal products to a greater degree than other dioxin-like PCB congeners.

Cancer risks and noncancer hazards were estimated for a range of tPCB EPCs and fractions of agricultural land within the floodplain with the following important findings:

- All cancer risks and nearly all noncancer HIs from consumption of garden produce and commercial dairy are below the EPA cancer risk range and noncancer hazard benchmark.

- Cancer risks from consumption of backyard and commercial beef and poultry and backyard dairy range from the low end of the risk range to a factor of 40 above the EPA risk range. Noncancer HIs typically exceed the EPA benchmark, except for those associated with an assumed tPCB EPC of 0.5 mg/kg.

- Risks for specific agricultural parcels may vary from predicted values presented in this assessment, depending on differences between assumed and actual tPCB soil concentrations and management practices. However, the results are presented in a format that allows the determination of risk for any parcel.

With respect to the TEQ concentration from dioxin-like PCB, dioxin, and furan congeners associated with the example of an assumed tPCB soil concentration of 2 mg/kg and a fraction of agricultural land in the floodplain equal to 1, the important findings were:

- Total TEQ cancer risk is primarily from dioxin-like PCB congeners, especially PCB-126.

- RME TEQ cancer risks for all commercial animal product scenarios exceed EPA's cancer risk range. The RME TEQ cancer risk also exceeds EPA's risk range for backyard dairy, beef, and egg scenarios. TEQ cancer risks for commercial and backyard produce are within the risk range.

- Milk fat TEQ concentrations predicted for commercial dairy farms are similar to or slightly greater than mean TEQ concentrations measured in the U.S. food supply.

- Predicted TEQ concentrations for commercial beef and poultry, and for backyard dairy, beef, and poultry are higher than TEQ concentrations measured in the U.S. food supply. In part, these differences reflect differences between farm management practices assumed in this assessment and management practices typical of U.S. farms.

- Cancer risks from consumption of agricultural products from the floodplain are likely underestimated by not simultaneously accounting for risk from tPCBs and from TEQ.

- Risks vary approximately linearly with soil tPCB concentration and fraction of agricultural land in the floodplain, and therefore, would be proportionately higher for EPCs greater than 2 and proportionately lower for fractions in the floodplain less than 1.